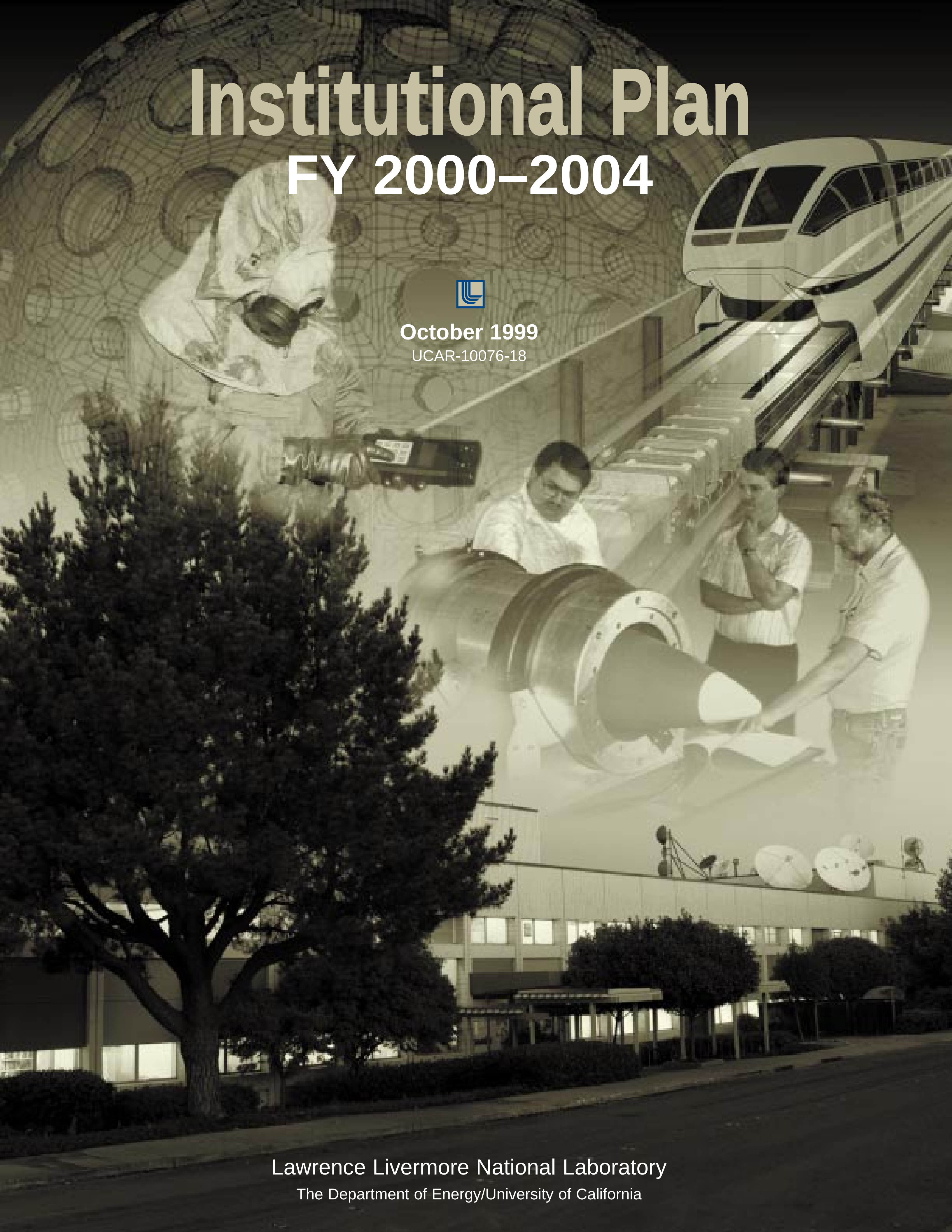
Institutional Plan

FY 2000–2004



October 1999

UCAR-10076-18

Lawrence Livermore National Laboratory

The Department of Energy/University of California

About the Cover

Engineering at Lawrence Livermore National Laboratory has always been known for doing the impossible—from manufacturing prototypes of smaller and smaller parts, to designing computer models to work faster and faster, to generating greater and greater power with lasers. Today, the Engineering Directorate is pioneering technologies that extend the range of solutions from microscale to ultrascale, often simultaneously. We call our breakthroughs at these poles "Xtreme Engineering."

The cover and divider pages of this year's Institutional Plan highlight Engineering's current important projects and accomplishments, often engineered from the "Xtremes" of science and technology at the Laboratory. On the cover is Engineering's "home" in Building 131, and above it are shown nationally recognized projects: PCRman, the world's only hand-held DNA analysis system for detecting pathogenic organisms, Inductrack scale model of a magnetically levitated train, vibration testing of a reentry vehicle, and (in the background) the computational mechanics TOPAZ3D code to predict expansion of the National Ignition Facility's target chamber.

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National Laboratory

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PREFACE

Navigating the Institutional Plan

This year, the *Institutional Plan* is divided into the following sections:

Section 1. Laboratory Overview

Livermore's mission, roles, and responsibilities as a DOE national laboratory and the foundation for decisions about the Laboratory's programs and operations.

Section 2. Laboratory Science and Technology—National Security

A description of the situations, issues, and planned thrusts of Livermore's national security programs: stockpile stewardship, countering the proliferation and use of weapons of mass destruction, and other defense-related activities.

Section 3. Laboratory Science and Technology—Enduring National Needs

A description of the situations, issues, and planned thrusts of Livermore's programs to meet enduring national needs—in energy, earth and environmental sciences, bioscience and biotechnology, and fundamental science and applied technology.

Section 4. Program Initiatives

Proposed significant additions to existing programs or new directions within our mission and a link to the major program that provides the foundation for the initiative.

Section 5. Laboratory Operations and Facilities

Facilities and human resources information, including Laboratory staff composition and diversity and status of facilities with links to Contract 48 management and the 1998 LLNL Comprehensive Site Plan.

Section 6. Appendices

- Program Resource Requirement Projections: Resource data for FY 2000–2004.
- LLNL Organization Chart.
- References for this Institutional Plan.

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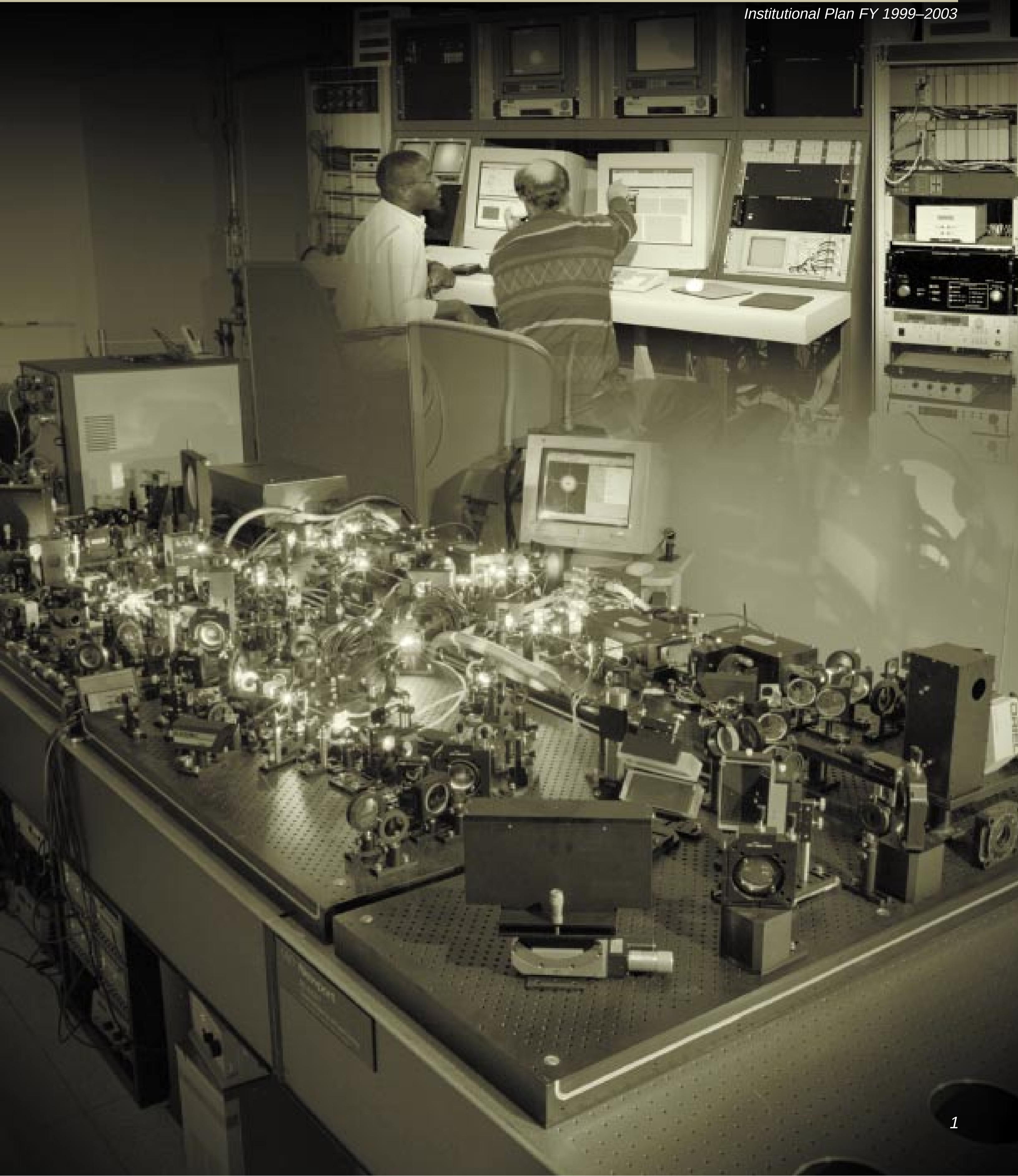
Institutional Plan FY 2000–2004

Department of Energy
Lawrence Livermore National Laboratory

DIRECTOR'S STATEMENT



During nuclear stockpile surveillance and refurbishment, weapons components must be disassembled in a way that minimizes damage to parts. Livermore recently delivered to the Oak Ridge Y-12 Plant a laser-cutting workstation that removes material atom by atom and effectively causes no heating of the part. The photos show the table-top workstation and controls used in this process that won an R&D 100 Award for Livermore engineers and scientists. Other applications could include precision cutting for high explosives, stainless steel, diamonds, tooth enamel, and heart tissue.

Director's Statement

C. Bruce Tarter
Director

The events of 1999 and our recent accomplishments provide a dynamic setting for the Lawrence Livermore National Laboratory's Institutional Plan FY2000-2004. It has been a year of significant achievements and major challenges to both our programs and the way we operate.

Our accomplishments and activities make clear our role as a Department of Energy (DOE) national laboratory. We are striving for major scientific and technical advances toward DOE's goals in national security, energy resources, environmental quality, and science and technology. We are also working to meet a standard of operational excellence that should be expected of a premiere national laboratory.

National security is our defining responsibility. We are a vital part of the DOE's extraordinarily demanding program to maintain a safe and reliable U.S. nuclear weapons stockpile in the absence of underground nuclear testing—a supreme national interest. In December 1999, a comprehensive internal DOE review of the Stockpile Stewardship Program was completed. Its overall assessment is that the program is sound and developing the science, technology and production capabilities needed to meet the program's challenging long-term goals.

It is our responsibility, together with Los Alamos and Sandia national laboratories, to provide accurate assessments of safety, security, and reliability of each weapon system. These assessments support a process of annual certification of the stockpile. The fourth annual certification was completed in December 1999. We also work with the DOE production facilities to extend the performance life of the weapons, and in 1999, we completed development activities that extend the lifetime of the W87, the Air Force's most modern ICBM warhead. February 1999 marked the completion of work on the first refurbished unit at the Pantex plant.

The Laboratory's national security responsibilities extend beyond stockpile stewardship. The proliferation of weapons of mass destruction (WMD)—nuclear, chemical, and biological—is a serious threat to national security. We are working with DOE and other organizations to provide technical support for U.S. arms control and nonproliferation policy, analyze weapons activities worldwide, and develop improved capabilities to thwart WMD threats. Livermore is making significant progress in technologies to secure weapons-usable fissile materials, to monitor and analyze proliferation-related production activities, and to detect the use of biological agents. Our future programs and plans are further described in this Institutional Plan.

Both major aspects of our national security mission—stockpile stewardship and nonproliferation—are very demanding. In particular, to meet the challenge of maintaining and refurbishing ever-aging U.S. nuclear weapons, the Stockpile Stewardship Program calls for major investments in vastly improved tools.

The National Ignition Facility (NIF) is a major investment that is under construction at the Laboratory. The NIF will provide the means for investigating the thermonuclear physics of primaries and secondaries in nuclear weapons. Construction of the building complex will be completed in 2001, and since the project began, the necessary tremendous advances have been made in new manufacturing processes for the many precision-optics components of the laser. The technology approach for the NIF is sound; however, issues have arisen about the method for assembling the lasers that affect the anticipated cost and schedule. We instated a new project team at Livermore and have benefited from the University of California's recommendations and insights based on an independent review of NIF. We are working closely with DOE to revise the project's cost and schedule. The Laboratory is committed to all actions necessary to ensure the timely success of NIF.

In addition, through the DOE's Accelerated Strategic Computing Initiative, we are using successively more powerful computers to improve our ability to simulate the performance of the aging stockpile and conditions affecting weapon safety. This year, we have achieved great successes using our Blue Pacific machine, capable of 3.8 trillion operations per second (3.8 teraops), and we expect to take delivery of a 10-teraops IBM supercomputer in 2000. In parallel with these acquisitions, we are improving simulation models and developing tools to manage and visualize the vast amount of data generated.

These major investments shape the Laboratory's future by enabling us to respond to a broad range of vital national needs. Livermore will have scientific computing capabilities that offer the potential of leading to unprecedented levels of understanding in climate and weather modeling, environmental studies, the design of new materials, molecular biology, astrophysics, and many other areas. And, with the NIF, we expect to create for the first time in a laboratory brief self-sustained fusion reactions. This accomplishment will be an important milestone on the road to developing fusion as a viable, clean source of energy.

As these research interests demonstrate, our focus is on the enduring missions of the DOE and program areas that reinforce our national security work. In the areas of energy and environment, we will be pursuing fusion energy research, applying our extraordinary computational capabilities to modeling the global climate, and further developing and applying novel groundwater remediation technologies. In addition, we will be extending our efforts in nuclear materials management—a long-term mission of DOE—including program integration and work in specific areas, such as Yucca Mountain project for nuclear-waste storage. In biosciences and biotechnology, we will build on the successes of the Joint Genome Institute, which plans to complete its work on the human genome ahead of the original schedule. We are developing programs in functional and structural genomics, as well as computational biology.

Increasingly, our major program activities are executed in partnerships with other laboratories, U.S. industry, and universities. Our partnerships with industry are many and varied. A particularly significant ongoing effort is our work as part of an industry–laboratories consortium to develop extreme ultraviolet lithography (EUVL) technologies for manufacturing the next generation of computer chips. The EUVL approach received an important vote of confidence this year at a workshop sponsored by International SEMATECH, a global consortium of semiconductor manufacturers.

Success also demands that we meet high operational standards. Currently, two areas of increased focus are safety and security. The Laboratory is taking steps to improve safety and our work environment to ensure that safety stays a top priority. In 1999, we began implementation at Livermore of DOE's Integrated Safety Management System (ISMS). We have already seen safety performance improve because of the added attention to the issue. By September 1999, all employees had completed ISMS training. DOE is currently reviewing our implementation plans and documentation.

Security at Livermore and our sister DOE national security laboratories, unfortunately, has been in news headlines all too often this year. Security is a responsibility that has always been taken seriously at the Laboratory, and it is becoming increasingly challenging as more information has become electronic, and science and technology have grown more international. During the year, we have made upgrades in the Laboratory's physical security systems to address arising concerns as well as new threats. Our counterintelligence program has grown, and we have further improved procedures for screening requests for foreign visitors and assignees. Most importantly, we are taking steps as part of a Tri-Laboratory Information Security Plan to upgrade cyber security at Livermore.

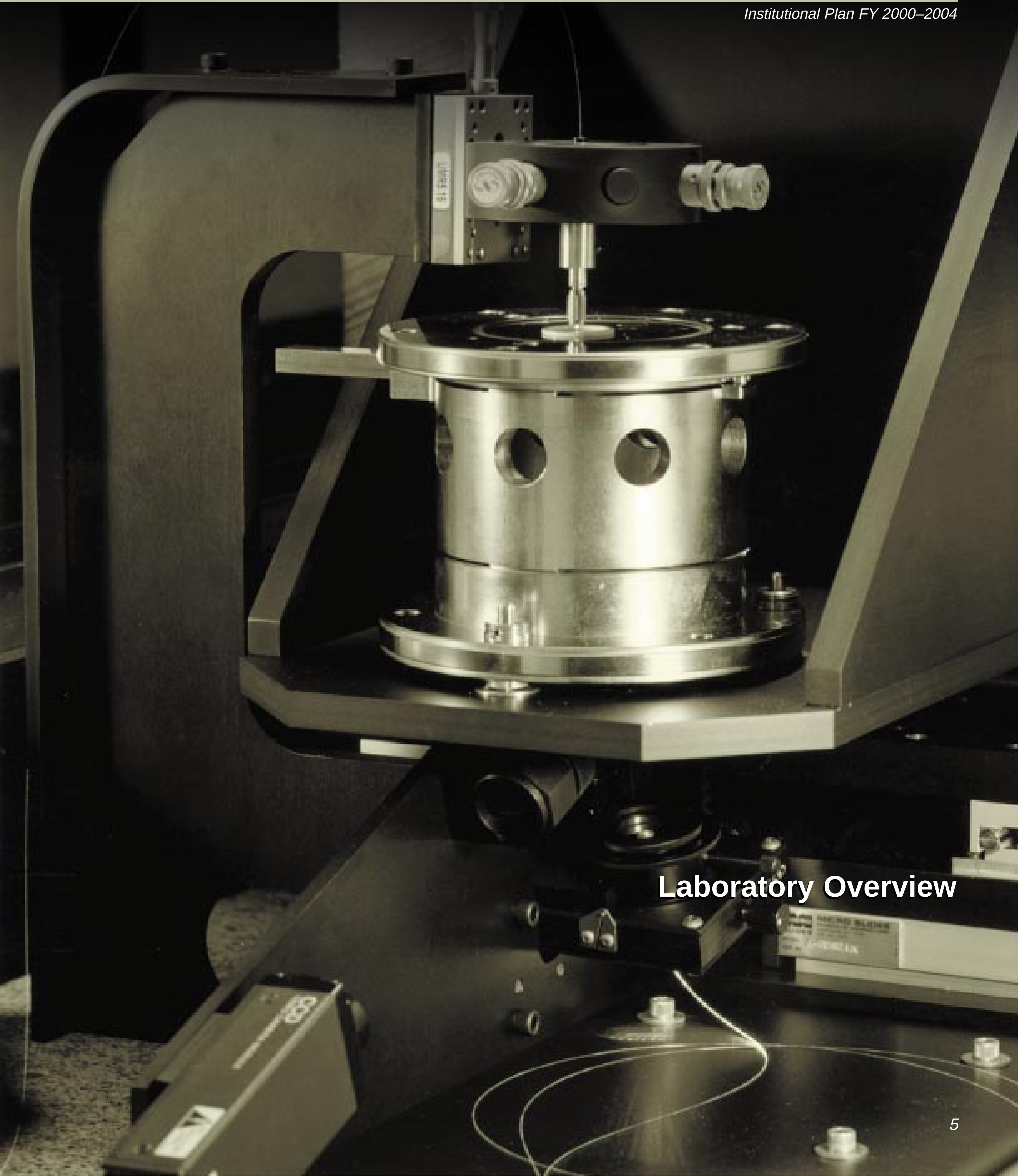
As we take steps to provide more protective security barriers, it is important to remember that security and science are both central to our mission and the way we operate. We cannot avoid—and to stay at the cutting-edge, we must not avoid—engaging the broad scientific community. The Laboratory depends on external interactions to be cognizant of major advances and to acquire special expertise needed to accomplish our mission goals.

The University of California, which manages Livermore, has been particularly helpful to both our programs and operations this year by taking an active role in addressing and resolving issues as they have arisen. Our association with the University and their oversight of our activities are important to the Laboratory's functioning and contribute to our successes.

This Institutional Plan describes our strategic plans and ongoing planning efforts, our current program accomplishments, and our new initiatives. Livermore's activities during this institutional planning period will help the Department to achieve success in its missions and, in the process, set the course for the Laboratory's programs in the early part of the 21st century. These activities will also set the course for future Laboratory operations—how we will work safely and efficiently with a wide variety of customers and partners and interact securely and effectively in an increasingly international scientific community.

At Livermore, we are ensuring national security and applying science and technology to the important problems of our time.

C. Bruce Tarter



Laboratory Overview

The Absolute Interferometer, a 1997 R&D 100 Award winner developed and engineered at Livermore, can measure "Xtremely" small errors—as small as just a few atoms—in the surfaces of optical parts. This metrological exactness is helping to make possible the next generation of high-power computer chips, produced using extreme ultraviolet projection lithography.

AT Lawrence Livermore National Laboratory, we are ensuring national security and applying science and technology to the important problems of our time.

Lawrence Livermore National Laboratory was founded in 1952 as a nuclear weapons laboratory. National security continues to be our defining mission. The Laboratory has been administered since its inception by the University of California, first for the Atomic Energy Commission and now for the U.S. Department of Energy (DOE). Through its long association with the University of California, the Laboratory has been able to recruit a world-class workforce and to establish an atmosphere of intellectual innovation, which is essential to sustained scientific and technical excellence. As a Department of Energy laboratory, Livermore has an essential and compelling core mission and the capabilities to solve important, difficult, real-world problems.

As this *FY2000-2004 Institutional Plan* highlights, it is a time of tremendous programmatic and operational challenges for the Laboratory:

- **Livermore programs must meet important commitments and deliver major products.** We are responsible for bringing into operation and applying significant new capabilities required for nuclear weapons stockpile stewardship, most notably the National Ignition Facility and a 10-teraops supercomputer. In addition, we are committed to other major efforts for sponsors that lay the foundation for future activities at the Laboratory.
- **The Laboratory is taking substantial steps to improve security and safety.** Recent events have reinforced the prime importance of security at the DOE nuclear weapons laboratories. Working closely with DOE Secretary Richardson, Livermore, Los Alamos, and Sandia national laboratories are expeditiously tightening security. At Livermore, we are taking specific actions to provide even greater protection of critical assets, implement state-of-the-art cyber security, and expand the Laboratory's counterintelligence program. We are also aggressively implementing DOE's Integrated Safety Management System to improve safety performance and management at Livermore.

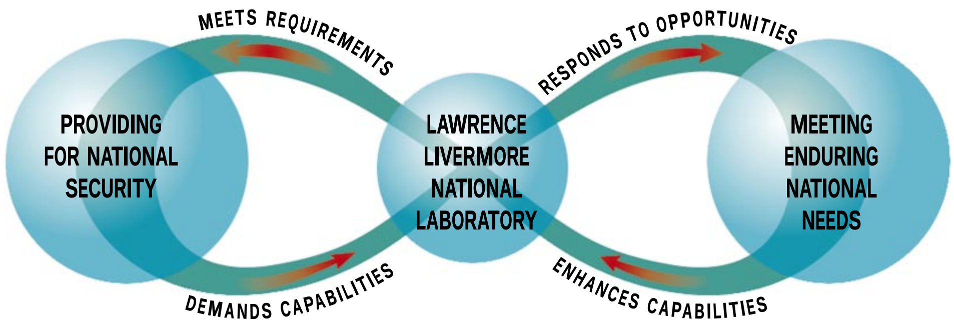


Figure 1-1. The Laboratory's mission. We meet requirements to provide for national security. This mission demands capabilities at the Laboratory that are used to respond to opportunities to meet enduring national needs through projects that enhance our capabilities.

1.1 Mission, Vision, and Goals

1.1.1 Mission

Lawrence Livermore National Laboratory is a premier applied-science national security laboratory. Our primary mission is to ensure that the nation's nuclear weapons remain safe, secure, and reliable and to prevent the spread and use of nuclear weapons worldwide. This mission enables our programs in advanced defense technologies, energy, environment, biosciences, and basic science to apply Livermore's unique capabilities and to enhance the competencies needed for our national security mission. The Laboratory serves as a resource to U.S. government and a partner with industry and academia. (See Figure 1-1.)

1.1.2 Vision and Goals

Our goal is to apply the very best science and technology to enhance the security and well-being of the nation and to make the world a safer place.

A Focus on National Security

National security is the defining responsibility of Lawrence Livermore National Laboratory. We are focusing the Laboratory's efforts on two of the nation's top priorities: ensuring the safety, security, and reliability of the U.S. nuclear stockpile and preventing and countering the proliferation of weapons of mass destruction. We will provide the world-class scientific and engineering capabilities that have made it possible for the U.S. to maintain the national deterrent while taking major

The Livermore Approach to Problem Solving

Multidisciplinary Research Teams. We form multidisciplinary teams tailored to meet the demands of each challenging problem. The teams combine scientific and engineering talent, and they draw from a diverse mixture of knowledge, skills, and experience to generate innovative solutions. Increasingly, research efforts entail partnerships with others outside the Laboratory as well.

An Integrated Approach to Research and Development. Research and development activities at Livermore range from fundamental science to production engineering of complex systems. We often carry concepts all the way from scientific discovery to fully developed prototype products.

Large-Scale Experimental Science and Engineering Development. We design and develop both products for our customers and large-scale experimental facilities, which we then use as tools to achieve program goals.

Computer Simulation of Complex Systems. Computer simulation is often the most cost-effective means for "conducting" a large number of complex experiments. Confidence in modeling results depends on careful validation through actual experiments. The use of simulations and experiments is mutually reinforcing.

steps in international arms control and arms reduction.

The realization of a world without nuclear testing—but with remaining dangers that keep nuclear deterrence and nonproliferation central elements of U.S. security strategy—presents new challenges. As part of an integrated national effort, we must make significant advances in science and technology to maintain confidence in the U.S. nuclear stockpile under a Comprehensive Test Ban Treaty. Drawing on these advances and the special expertise of the Laboratory, we will also work with various U.S. government agencies to improve international nuclear safety and halt and prevent the use of nuclear, chemical, and biological weapons by developing needed technologies and analysis tools. In addition, Livermore will continue to apply its scientific and engineering capabilities to develop advanced defense technologies to increase the effectiveness of U.S. military forces.

As a national security laboratory, we are committed to protecting sensitive information and special nuclear materials and are using increasingly sophisticated measures to do so.

Major Investments at Livermore

Investments are being made at the Laboratory in cutting-edge computational and experimental tools needed to help ensure that the U.S. nuclear weapons stockpile remains safe and reliable. Livermore will have scientific computing capabilities that offer the potential for revolutionary advances in many areas of science and technology as we make necessary improvements to simulation models of nuclear weapon performance. Livermore is also the site for the National Ignition Facility, which will be the world's largest laser system and will provide the means for investigating the thermonuclear physics of weapons in the absence of nuclear testing and for exploring the promise of fusion energy. These major investments shape the future of the Laboratory.

Meeting Enduring National Needs

An exceptional staff with state-of-the art research capabilities will enable the Laboratory to respond to a broad range of vital national needs. With Livermore's emphasis on high-payoff results, many projects will entail significant scientific and technical risk. We seek such challenges and will contribute where Laboratory efforts can lead to dramatic benefits for the nation.

Our special focus will remain on the critical, enduring missions of the Department of Energy and the program areas that positively reinforce our national security work. Livermore will pursue projects aimed at significant, large-scale innovations in energy production to ensure abundant, clean, and affordable energy for the future. Environmental efforts will be directed at demonstrating effective remediation technologies, advancing the science base for environmental regulation, improving the stewardship of nuclear materials in the U.S., and modeling more accurately regional weather and global climate conditions. We will also serve as an effective national technical resource in the stewardship of nuclear materials. The Laboratory's bioscience research will advance human health through efforts focused on genomics, disease susceptibility and prevention, and improved healthcare and medical biotechnology. In other fields, Livermore researchers will pursue science and technology initiatives that have the potential for major advances and that bolster the Laboratory's scientific and technological strengths. Increasingly, our accomplishments will be achieved through effective partnerships with others.

Focused Internal Investments

The foundation for Livermore's diverse set of research and development activities—now and in the future—is the Laboratory's science and technology base, which we will sustain through effectively managed internal investments. Excellence in science and technology will keep the Laboratory vibrant and healthy and able to respond to new challenges.

Safe, Secure, and Efficient Operations

Livermore's scientific and technological achievements will be made possible by safe, secure, and efficient operations and sound business practices. The Laboratory is committed to providing every employee and the community with a safe and healthy environment in which work and live. We are also taking specific steps to provide even greater protection of critical assets at Livermore, implement state-of-the-art cyber security, and expand the Laboratory's counterintelligence program.

1.2 Critical Capabilities

The Laboratory is a national resource of science and technology with an extensive science and technology base and many specialized research capabilities and facilities. Livermore provides leadership in several broad research areas that are central to the Laboratory's missions.

1.2.1 An Extensive Science and Technology Base

Livermore programs are supported by a large technical base consisting of more than 1,200 Ph.D. scientists and engineers. A significant portion of the scientific staff is organized into "discipline" directorates—Chemistry and Materials Science, Computations, Engineering, and Physics—and many of these people are matrixed, or assigned, to specific programs. Use of the matrix system fosters efficient transfer of technical knowledge among programs, enables staff members to develop a wide-ranging set of skills and knowledge, and infuses projects with diverse ideas for solutions. As a result, the Laboratory has the ability to seize program opportunities, the agility to react quickly to technical surprises, and the flexibility to respond to programmatic changes.

The Laboratory's many research and development accomplishments demonstrate Livermore's leadership in several broad research areas.

High-Energy-Density Physics and Nuclear Science and Technology. For over 45 years, the Laboratory has demonstrated excellence in science and technology directed at the development of nuclear weapons and the harnessing of thermonuclear and fission energy for civilian power. We have broad expertise in nuclear science and technology as well as exceptional capabilities for investigating the properties of matter at extreme conditions (up to stellar temperatures and pressures) and interaction of matter with intense radiation. This expertise will remain crucial for our national security programs. It will also be applied to develop innovative techniques for environmental cleanup, assist the Department of Energy in the stewardship of nuclear materials, and advance fundamental science in many areas.

Advanced Lasers and Electro-Optics. Livermore is the pre-eminent laser science and technology laboratory in the world.Our efforts are are strongly focused on construction of the National Ignition Facility. We are also applying the Laboratory's expertise in lasers and electro-optics to meet other national needs, contribute to the competitiveness of U.S. industry, and address issues in basic science. (See Figure 1-2.)

High-Performance Scientific Computing. Over the 1994–2004 decade, we are acquiring successively more powerful computers with the goal of achieving increases in computational speed and data capacity by a factor of 100,000. By summer 2000, we expect to have a 10-teraops computer (10 trillion operations per second), capable of performing calculations in 5 minutes that would have taken 40 days to complete in 1997. While meeting the Laboratory's commitments to national security programs, we are making internal investments to ensure that all major

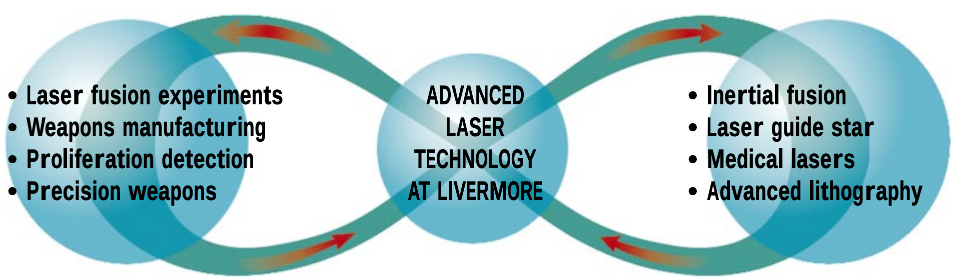


Figure 1-2. Expertise in advanced lasers and associated technologies, necessary for the National Ignition Facility and other major projects for national security, provides program opportunities in inertial confinement fusion, advanced lithography, and other diverse scientific and industrial applications.

programs at the Laboratory have access to these advanced computing capabilities. They offer the potential of revolutionizing scientific discovery and leading to unprecedented levels of understanding in climate and weather modeling, environmental studies, the design of new materials, and many areas of physics.

Materials Science. In support of Laboratory programs, we have developed wide-ranging expertise about materials. In addition to conducting fundamental research on the properties of materials, we engineer novel materials at the atomic or near-atomic levels. Livermore's stockpile stewardship responsibilities require researchers to understand in great detail the properties of very complex materials—ranging from plutonium to organic materials, such as high explosives—and how materials age in the presence of radiation and other toxic materials. Expertise in chemistry and materials science also provides critical support to many other program areas at the Laboratory, such as environmental cleanup, nuclear waste disposal, and atmospheric modeling. In addition, we develop nano-engineered multilayer materials and other exotic materials, such as aerogels. These advances meet programmatic needs for highly efficient energy-storage components, ultralight structural materials, tailored coatings, and novel electronic, magnetic, and optical materials.

1.2.2 Specialized Research Capabilities and Facilities

Many specialized research capabilities and facilities exist at Livermore. Because of our overall size, the need for technologies and capabilities that do not exist elsewhere, and the fact that essential elements of

Principal Research Capabilities and Facilities at Livermore

Center for Accelerator Mass Spectrometry—most versatile spectrometry capability in the world.
Chemistry and Materials Science Environmental Services Laboratory—wide-ranging capability to provide chemical and radiochemical characterization of environmental samples.
Conflict Simulation Laboratory—state-of-the-art, interactive, entity-level conflict simulation.
Electron Beam Ion Trap Facility—first achievement of totally ionized uranium not using a high-energy accelerator.
Engineering Technology Centers—cutting-edge research at the Centers for Complex Distributed Systems, Computational Engineering, Microtechnology, Nondestructive Evaluation, and Precision Engineering.
Flash X-Ray Facility—a versatile hydrodynamic testing facility currently undergoing upgrades.
Forensic Science Center—world leadership in development of new forensic capabilities and instrumentation.
Genome Center—home of world's largest collection of cloned genes and the most detailed map of a human chromosome.
Hardened Test Facility—provides capability for mechanical testing of weapons components.
High Explosives Applications Facility—world's most modern high-explosives research facility.
Large Optics Diamond Turning Machine—world's most accurate machine tool for fabricating large metal optical parts.
National Atmospheric Release Advisory Center—for real-time emergency predictions for hazardous substance releases.
4-MeV Pelletron—versatile particle accelerator for materials analysis and radiation effects studies.
Plutonium Facility—modern facility for nuclear materials research and testing.
Positron Microscope—world's most intense pulsed proton beam for studying material defects.
Secure and Open Computing Facilities—the Laboratory's supercomputers and testbed for hardware and software development.
Superconducting Magnet Test Facility—unique development testing facility for large superconducting magnets.
300-keV Transmission Electron Microscope—provides important chemical and structural information about materials at the near-atomic level.
Tritium Facility—supports ICF target fabrication and decommissioning and recycling activities.
Two-Stage Gas Guns—first achievement of metallic hydrogen.
Ultra-Short Pulse Laser—for equation-of-state, opacity, and other stockpile stewardship experiments.
Uranium Manufacturing and Process Development Facility—supports research on casting and forming processes.

our national security mission are classified, much of the necessary expertise to support programs resides within the Laboratory. For example, we have capabilities to develop state-of-the-art instrumentation for detecting, measuring, and analyzing a wide range of physical events. We also have significant expertise to support innovative applied-science efforts in advanced materials, precision engineering; microfabrication, nondestructive evaluation, complex-system control and automation, and chemical, biological, and photon processes.

1.2.3 Multiprogram Support for DOE

As a consequence of the Laboratory's extensive science and technology base and its many special research capabilities, we provide multiprogram support to the DOE. This important relationship between the capabilities the Laboratory has to pursue its national security mission and its ability to make unique and valuable contributions in other DOE mission areas is a central feature of Livermore's mission statement (see Figure 1-1).

For example, with outstanding capabilities in laser science and technology, we support stockpile stewardship, pursue inertial confinement fusion physics, develop lasers for biotechnology and advanced manufacturing applications, and apply advances in laser technology to make breakthroughs in areas of basic science (see Figure 1-2). Our expertise in bioscience and bioengineering has applications in genomics research, bioremediation, environmental risk reduction, and biological warfare agent detection. Advanced scientific computing at Livermore supports stockpile stewardship, atmospheric modeling for emergency response and global climate prediction, computational

From *Creating the Laboratory's Future...*

PROVIDING FOR NATIONAL SECURITY
"National security is the defining responsibility of the Laboratory."

MEETING ENDURING NATIONAL NEEDS
"Our focus will remain on the critical, enduring missions of the DOE and program areas that positively reinforce our national security work."

MISSION-DIRECTED SCIENCE AND TECHNOLOGY
"Livermore's strengths are well matched to DOE's needs . . . We pursue major projects where we can make unique and valuable contributions. These activities build on and reinforce the Laboratory's key strengths."

AN OUTSTANDING WORKFORCE
"Challenging scientific programs, world-class research facilities, and a collegial environment are critical to attracting and retaining an outstanding workforce."

INVESTING IN THE FUTURE
"Excellence in science and technology will keep the Laboratory vibrant and healthy and able to respond to new challenges."

MANAGING OPERATIONS EFFECTIVELY
"Safe and efficient operations, sound business practices, and attention to the Laboratory's valuable resources make possible Livermore's technical achievements."

PARTNERSHIPS THAT CREATE CAPABILITIES
"We are involved in collaborations as a means to accomplish our goals, an expansion of the original E. O. Lawrence model of team science."

biology, modeling for radioactive waste disposition and the movement of contaminants in ground water, materials science modeling, and many other scientific areas (see Figure 1-3, below).

1.3 Strategy Development and Alignment

1.3.1 Development of a Strategy—The DOE Strategic Plan

The *U.S. Department of Energy Strategic Plan* (September 1997) articulates the Department's mission, vision for the future, core values, and strategic goals in its four businesses: National Security, Energy Resources, Environmental Quality, and Science and Technology. The strategic goals identified in the plan are:

- **National Security.** Support national security, promote international nuclear safety, and reduce the global danger from weapons of mass destruction.
- **Energy Resources.** Promote with the Department of Energy secure, competitive, and environmentally responsible energy systems that serve the needs of the public.
- **Environmental Quality.** Aggressively clean up the environmental legacy of nuclear weapons and civilian nuclear R&D programs, minimize future waste generation, safely manage nuclear materials, and permanently dispose of the nation's radioactive wastes.
- **Science and Technology.** Deliver the scientific understanding and technological innovations that are critical to the success of DOE's mission and the nation's science base.

1.3.2 Strategy Development and Identification of Key Milestones

The Laboratory's strategy document, *Creating the Laboratory's Future*, provides the basis for this Institutional Plan. First issued in September 1997, *Creating the Laboratory's Future* continues to reflect our view of Livermore's responsibilities in meeting the strategic goals of DOE. The Laboratory's strategy was developed through the efforts of the five Strategic Councils at the Laboratory and the Policy, Planning, and Special Studies Office, which took the lead in synthesizing the work of the councils for senior management review.

The Laboratory's Strategic Councils. The five Strategic Councils were created by the Laboratory Director in 1996 to provide Laboratory-wide strategic direction in their domain of responsibility. Three councils focus on major business lines of the Laboratory: the Council on National Security, the Council on Energy and Environmental Systems, and the Council on Bioscience and Biotechnology. The Council on Strategic Science and Technology focuses its attention on issues pertaining to the scientific and engineering base at the Laboratory. In addition, there is a Council on Strategic Operations. The councils provide a key link that helps to ensure that the Laboratory's program plans and deliverables match the plans and needs of the DOE and other customers (See Figure 1-4.).

The Laboratory's five councils, consisting of a senior-management chairperson and a select group of Associate Directors (or their representatives), are responsible for both tactical planning and formulating a strategy for long-range program and resource development in their areas. The councils provide guidance and are part of the review process for Laboratory Directed Research and Development. They also developed planning materials for *Creating the Laboratory's Future* and ensure that the strategic direction of planned actions and initiatives aligns with the strategic plans of the Department of Energy (and other sponsors of work). In addition, the councils are responsible for developing materials about plans and programs that are used at annual senior management offsite meetings, during which priorities are established for the coming year.

Livermore's Strategy Document. *Creating the Laboratory's Future* describes Livermore's roles and responsibilities as a DOE national laboratory and sets the foundation for decisions about Laboratory programs and operations. It presents the Laboratory's mission, vision, and goals (Section 1.1); projects and initiatives in support of them; the science and technology strengths of the Laboratory

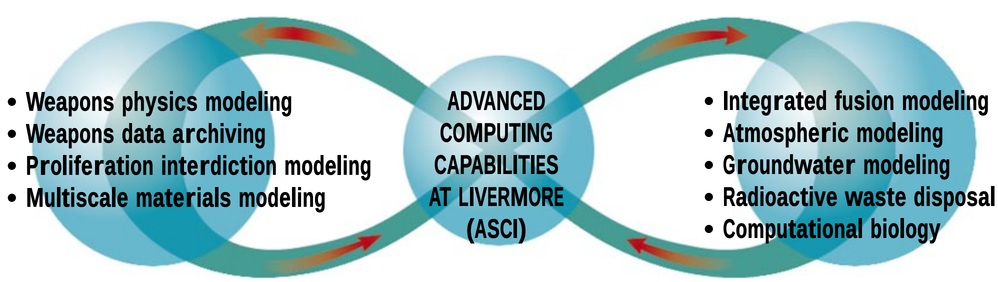


Figure 1-3. The Accelerated Strategic Computing Initiative (ASCI) and Livermore's advanced scientific computing capabilities, required for stockpile stewardship, enable us to respond to other program opportunities.

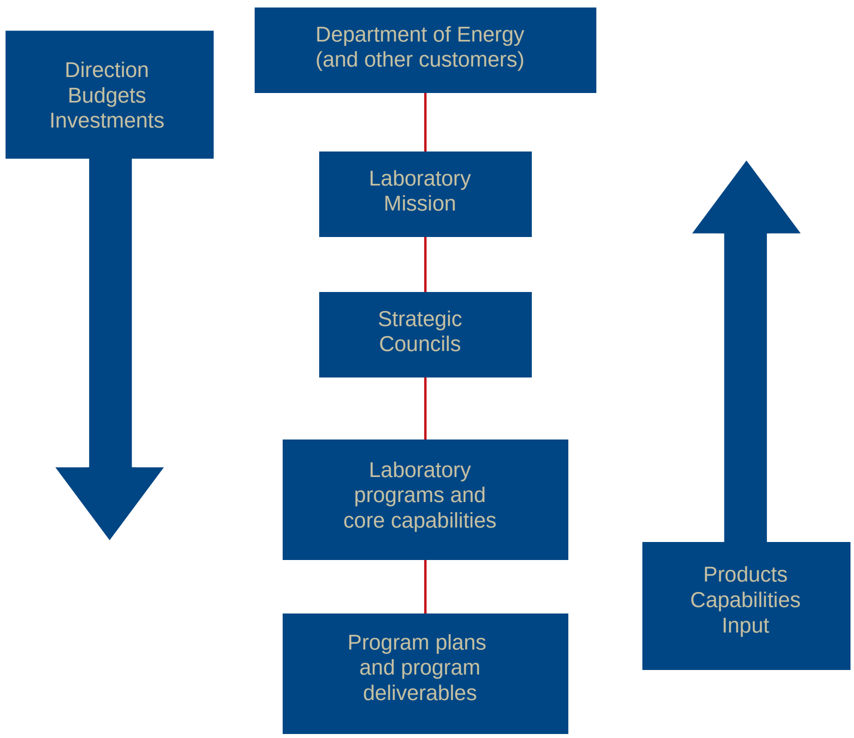


Figure 1-4. Development and alignment of Livermore's strategic plans are highly interactive processes involving the Department of Energy (as well as other customers) and the Laboratory's programs and strategic councils. Strategic direction and major new investments at Livermore, which flow down from the DOE, are based on recognition of the Laboratory's capabilities, responsibilities, and current deliverables.

that support our missions (Section 1.2); the management of operations at the Laboratory (and operations initiatives); and steps we are taking to prepare for the future.

Milestones for the Year 2001. A product of the Laboratory senior management offsite in February 1999 was a list of goals, or milestones (Figure 1-5), for Livermore to achieve by January 2001. The list of 12 milestones represent goals for the Laboratory as a whole; other important objectives more focused on specific programs are not included. Achievement of these twelve challenging milestones will help to define the Laboratory's long-term roles in program areas that are of national interest and importance.

In many instances, accomplishments represented by the 2001 milestones are not new items. Rather, the list identifies the completion of programs now under way or, in some cases, progress toward completion. When an unanticipated event occurs, such as the cancellation of the Atomic Vapor Laser Isotope Separation project by the U.S. Enrichment Corporation in June 1999, we have adjusted the goal—in this case our industrial partnerships milestone. Similarly, as a consequence of significant issues that arose since February 1999 concerning the construction of the National Ignition Facility, the third milestone in the list has been updated to be consistent with current goals.

1.3.3 Alignment with DOE Strategy and Needs

Livermore's Principal Responsibilities and Major Programs. The Laboratory's mission statement—and essentially all the supporting material in *Creating the Laboratory's Future*—highlights the important interaction among Livermore's primary mission (national security), the scientific and technical capabilities at the Laboratory, and programs to meet enduring national needs (other than national security). The direction of the Laboratory's national security programs—evident from the milestones for 2001—is discussed in Section 2 of this Institutional Plan. In providing for national security, Livermore's principal responsibilities are:

- Stewardship of the U.S. nuclear weapon stockpile.
- Stemming the proliferation of weapons of mass destruction.
- Responding to other important national security needs through application of Livermore's science and technology.

Requirements to provide for national security demand unique capabilities at the Laboratory, which are also used to respond to opportunities to meet broader national needs. As discussed in Section 3 of this Institutional Plan, our focus is on the critical, enduring missions of the DOE and program areas that reinforce our national security work. Where we are able to make unique and valuable contributions, Livermore pursues major projects directed at:

- Energy security and long-term energy needs.
- Environmental assessment and management.
- Bioscience advances to improve human health.

• Breakthroughs in fundamental science and technology.

As highlighted in the 2001 milestones, we are able to make selected advances in many of DOE's mission areas, in part because our approach to research and development is multidisciplinary, integrating many disciplines with cutting-edge capabilities in multiple areas of science and technology.

For example, Livermore's Biology and Biotechnology Research Program is at the forefront of genomics research in part because of the Laboratory's capabilities and success at engineering development of technologies for high-speed sorting of individual chromosomes and for measuring distances between DNA markers. Bioscience expertise, in turn, is contributing to the development of novel bioremediation technologies for groundwater cleanup and portable minisensors for rapid, accurate detection and characterization of biological warfare agents in the field. Opportunities to meet a broad range of national needs are created by our other special capabilities, such as in advanced lasers (Figure 1-2) and advanced scientific computing (Figure 1-3).

Alignment with the DOE Strategic Plan. The nearly continual interactions of Livermore programs with DOE sponsors and frequent interactions of senior Laboratory managers with DOE Program Secretarial Officers (PSOs) greatly contribute to alignment of the Laboratory's strategic direction with the *U.S. Department of Energy Strategic Plan* (September 1997) and the commitments made in the Secretary of Energy's Performance Agreement with the President for FY 1999. Moreover, as exemplified by the Stockpile Stewardship Program, key Laboratory program leaders and staff work with and provide information to assist DOE PSOs in formulating DOE's strategic plans and direction. These activities feed back into the Laboratory's strategic

Figure 1-5. Twelve Milestones for Livermore to Make by 2001

1. The Stockpile Stewardship Program is proceeding as planned, and the stockpile has been certified for the fifth time without the need for nuclear testing.
2. The Laboratory has made significant gains in improving safety and is now viewed as a leader in the DOE complex. Livermore's operational record in counterintelligence and physical security continues to be viewed as excellent, and the Laboratory has made state-of-the-art advances in cyber security.
3. The National Ignition Facility building complex is complete, and laser support equipment is being installed.
4. The 10-teraops computer for the Accelerated Strategic Computing Initiative is fully operational for stockpile stewardship calculations, and Livermore is helping to drive all aspects of high-performance computing.
5. The Laboratory is providing technology and capabilities to protect the United States from nuclear, chemical, biological, and other emerging threats to national security.
6. Livermore has become the leading DOE laboratory in industrial partnering, with extreme-ultraviolet lithography among the largest DOE successes to date.
7. The Joint Genome Institute has exceeded its sequencing goals, and the Laboratory has built support for follow-on efforts in functional genomics and structural biology.
8. Livermore has expanded initiatives in nuclear materials stewardship, Visalia clean-up technology, and global climate modeling.
9. The workforce and management reflect an ability to attract and retain a high-quality and diverse staff.
10. The Laboratory's science and technology contributions are recognized by prizes, awards, and front-page publicity.
11. The Long-Range Strategy Project has successfully completed its work with a visionary and compelling description of the Laboratory's future.
12. The Laboratory is increasingly recognized as integral to the state of California through increased involvement with the University of California, particularly at the Davis and (new) Merced campuses, and as a partner of the state's broad education initiatives.

planning process and assure that Livermore programs and strategies align with those of the DOE (Figure 1-6).

Support for the Secretary of Energy's Performance Agreement. The alignment of Livermore's programs and plans with those of DOE is further demonstrated by the support that the Laboratory's 2001 milestones provide to the objectives and commitments set out in the Secretary of Energy's Performance Agreement. Each year since FY 1995, the DOE has developed Annual Performance Agreements, which are now a key component of the Department's Strategic Management System. They establish specific commitments and measures related to the goals and strategies in the Department's Strategic Plan. Figure 1-7 illustrates the alignment of Livermore's 2001 milestones with objectives defined in the FY 1999 Performance Agreement,

Self-Assessments of Planning Success. In our self-assessment of Laboratory planning for DOE and the University of California (Section 1.4), we evaluate success and alignment with DOE's strategic direction and plans through consideration of four factors:

- Successful Programs and Partnerships. Sustained support for program activities at the Laboratory are indicative of our efforts to align with the DOE's plans and goals and of executive-branch and congressional recognition of the importance of the work and the progress being made. Increasingly, Livermore's programs are being pursued in partnership with other laboratories, academia, and industry. The formation and successful management of these partnerships also reflect on effective planning.
- Major Investments at the Laboratory. Successful planning is evident in the fact that major investments in capabilities and facilities are being made at Livermore. In addition, our special capabilities are being effectively used in programs sponsored by DOE and others.
- New Initiatives with DOE. Livermore is at the forefront of planning and execution of several new DOE initiatives, indicating that our plans are well aligned with those of the Department.
- Awards and Honors. The awards and honors we receive demonstrate the quality of science and technology at the Laboratory. A strong science and technology base at Livermore makes it possible for us to be very responsive to and stay aligned with the changing needs of DOE.

1.3.4 Anticipating and Responding to Future Needs

In addition to its programmatic responsibilities, Livermore—as a national laboratory—serves as a technical resource for the federal government to underpin the development of effective public policy. To meet this responsibility, the Laboratory must

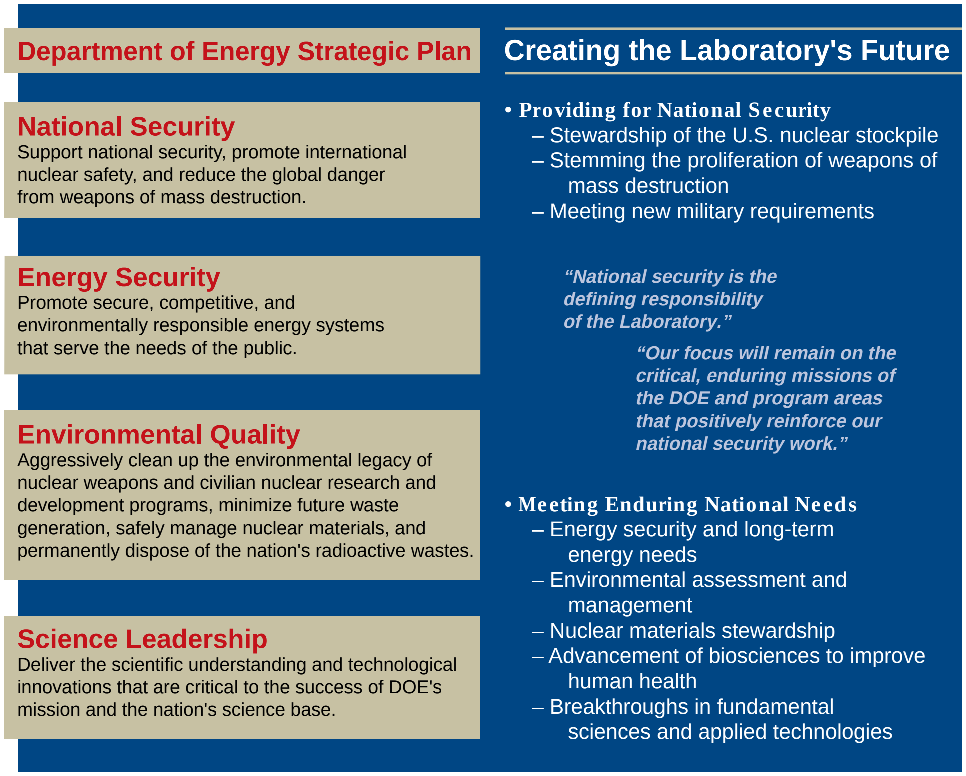


Figure 1-6. The missions and goals identified in the Laboratory's strategy document, *Creating the Laboratory's Future*, closely align with the strategic goals identified in the *U.S. Department of Energy's Strategic Plan* (September 1997).

Figure 1-7. Alignment of Livermore's 2001 Milestones with Relevant Objectives in DOE's FY 1999 Performance Agreement.

Performance Agreement Objective	Supporting Laboratory Milestones[1]
National Security	
NS1: Maintain confidence in the safety, reliability, and performance of the nuclear weapons stockpile without nuclear testing.	1, 3, 4
NS2: Replace nuclear testing with a Stockpile Stewardship Program.	1, 3, 4
NS3: Ensure the vitality of DOE's national security enterprise.	2, 3, 4, 9, 11
NS4: Reduce nuclear weapons stockpiles and the proliferation threat caused by the possible diversion of nuclear materials.	5, 8
NS5: Continue leadership in policy support and technology development for international arms control and nonproliferation efforts.	5
NS7: Improve international nuclear safety.	5, 8
Energy Resources	
ER5: Carry out information collection, analysis, and research that will facilitate development of informed positions on long-term energy supply and use alternatives.	3, 8
Environmental Quality	
EQ1: Reduce the most serious risks from the environmental legacy of the U.S. nuclear weapons complex first.	8
EQ2: Clean up as many as possible of the Department's 53 remaining contaminated geographic sites by 2006.	8
EQ5: Dispose of high-level radioactive waste and spent nuclear fuel in accordance with the Nuclear Waste Policy Act as amended.	8
EQ6: Reduce the life-cycle costs of environmental cleanup.	8
EQ7: Maximize the beneficial reuse of land and effectively control risks from residual contamination.	8
Science and Technology	
ST1: Develop the science that underlies DOE's long-term mission.	3, 4, 7, 8, 10, 11
ST2: Deliver leading-edge technologies that are critical to the DOE mission and the nation.	4, 5, 6, 7, 11
ST4: Assist in the government-wide effort to advance the nation's science education and literacy.	10, 12
Corporate Management	
CM1: Ensure the safety and health of the DOE workforce and the public and ensure the protection of the environment in all Departmental activities.	2

[1]Milestone numbers are from the 12 Milestones, p. 14.

maintain its vitality by anticipating and changing to meet evolving national needs. We work with DOE and other sponsors to anticipate the future needs of the nation, keep them apprised of emerging technical opportunities, and identify areas where science and technology can enhance national security and well-being. To be effective, we must continue to be an integral and active part of the nation's science and technology infrastructure, by participating in the national dialogue on important science issues and being broadly recognized as a scientific leader.

Focused Internal Investments. We must continue to make internal investments that develop the skills and capabilities needed to meet customers' future needs. The present strengths of Livermore are, in large part, a product of investment choices in the past. An important source of internal investment is Livermore's Laboratory Directed Research and Development (LDRD) Program. LDRD is an important tool we have for supporting research and development projects that will enhance the Laboratory's core strengths, nurture research efforts that expand the Laboratory's scientific and technical horizons, and create important new capabilities so that the Laboratory can respond promptly and effectively to new missions and national priorities. Livermore's LDRD Program has been very productive since its inception in FY 1985, with an outstanding record of scientific and technical output. Program accomplishments (highlighted in Section 3.3) are more fully described in Livermore's LDRD Annual Reports.

The Long-Range Strategy Project. One of the steps we have taken to better define future directions for the Laboratory is the formation of the Long-Range Strategy Project. The Long-Range Strategy Project is exploring science and technology opportunities and national program needs in the 2010-to-2020 time frame. The project was launched in 1998 with the recognition that Livermore's prospects 10 to 20 years in the future are uncertain. Technology is evolving very rapidly, and programmatic uncertainties arise from the fact that post–Cold War national research and development priorities remain the subject of a national debate. The Long-Range Strategy Project entails the efforts of 22 younger leaders at the Laboratory—spanning disciplines and programs—guided by the Director and the Deputy Director for Science and Technology, led by the Director of Policy, Planning, and Special Studies, and supported by a resource group of selected senior Laboratory leaders.

Project participants are meeting with an array of leaders from diverse fields and enterprises and are having in-depth discussions with each of the Associate Directors and other senior Livermore scientists and engineers. They are focusing their efforts on selected topics, which are being pursued through topical subgroups. The first set of topics included: nuclear deterrence in the 21st century, computations and communications, bioscience and biotechnology, and the future of public and private R&D. The second set of topics being considered includes: emerging national security threats, the "middle third" of the Laboratory (e.g., energy, environment, and supporting disciplines), the public policy landscape in 2015, and the Laboratory workplace in 2015. The results of these and other focused study efforts will form part of the overall project report recommendations. The Long-Range Strategy Project will be active for about 18 months, with a synthesis report to be completed by January 2000.

1.4 Evaluation of Performance

Livermore is one of three national laboratories managed and operated under a contract between the Department of Energy and the University of California (UC). When the DOE–UC contract was revised and extended in 1992, DOE and UC pioneered performance-based contracting as applied to government-owned, contractor-operated (GOCO) institutions. In 1997, DOE and UC agreed to extend the contract for five years. The 1997 contract extension preserves and strengthens the performance-based management system introduced in 1992.

In addition to UC's annual review of our performance, their active management oversight of the Laboratory's programs and operations is particularly beneficial. The UC Board of Regents Committee of Oversight of the Laboratories, the UC President's Councils on the National Laboratories, and other issue-specific special review panels greatly contribute to our functioning and our successes.

DOE publishes an annual appraisal of the Laboratory's performance through a process that culminates in performance ratings for the Laboratory (see Figure 1-8). The appraisal process is grounded on Appendix F of the DOE/UC management and operating contract. It contains about 90 performance measures that provide the basis for the performance management system. Performance is measured in two areas: (1) science and technology and (2) administration and operations, which includes such items as environmental,

safety, and health (ES&H), safeguards and security, business operations, facilities management, and human resources. Each year, Livermore provides to UC the Science and Technology Assessment Report, prepared by the Laboratory Science and Technology Office, and the Appendix F Self-Assessment Report, coordinated by the Laboratory Office of Contract Management, which covers administrative and operations.
UC reviews these self-assessments and prepares an overall report that it submits to DOE. DOE, in turn, uses these materials and issues an annual appraisal of the Laboratory's performance.

As shown in Figure 1-8, since the inception of performance assessment system in FY 1993, the Laboratory has achieved very high ratings in science and technology and has steadily improved overall ratings in administration and operations, although there remain selected areas, such as safety and security, where we can improve. Livermore's performance evaluation in FY 1998 was "outstanding" in science and technology and "excellent" in administration and operations.

At the same time that overall Laboratory ratings have increased, the cost of traditional overhead and operational support has decreased significantly. The decrease has supported strategic reinvestments in the Laboratory's infrastructure and has made it possible for a greater share of resources to be shifted to scientific programs, enhancing the Laboratory's overall mission performance.

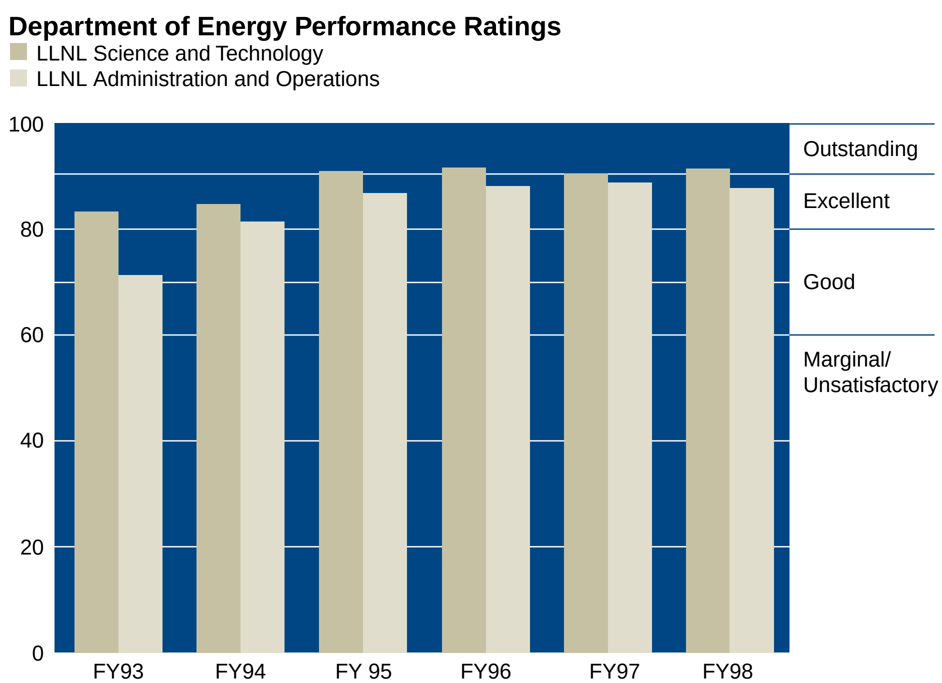
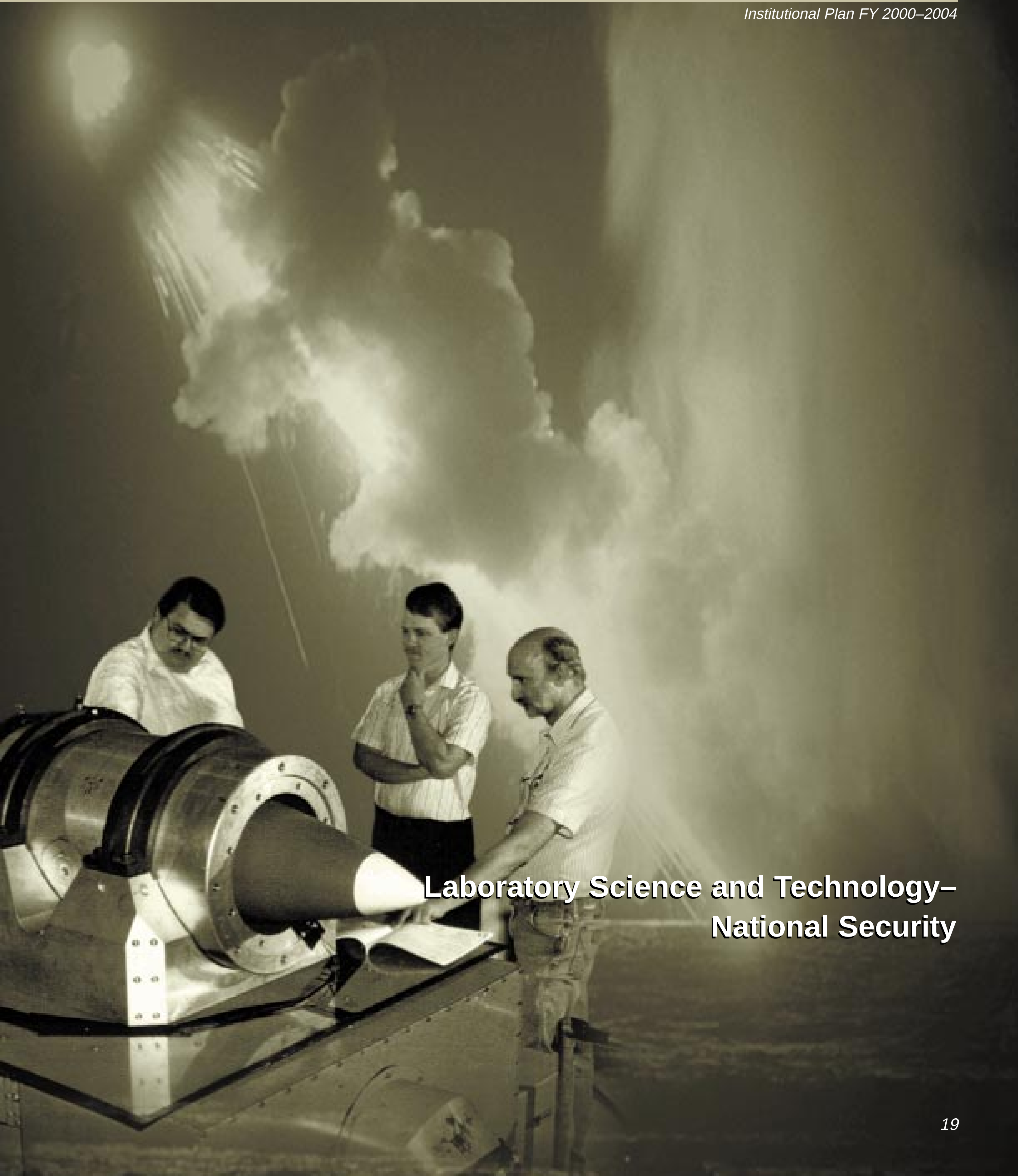


Figure 1-8. Overall, Livermore's Science and Technology (S&T) was deemed "outstanding" and Administration and Operations (A&O) "excellent" as measured by performance criteria defined in the performance-based management contract between the Department of Energy and the University of California.

SECTION 2



Laboratory Science and Technology– National Security

Engineers examine a Livermore-designed warhead after a vibration test at our Site 300 Experimental Test Site. As part of the W87 Life-Extension Program, Livermore also contributes to onboard diagnostics and telemetry used in a reentry vehicle flight test (above) that provides confidence in the reliability of the refurbished W87 warhead under operational conditions.

LAWRENCE Livermore National Laboratory was founded in 1952 as a nuclear weapons laboratory. National security remains Livermore's defining mission. The world has undergone significant changes since then, and, like the world, our mission has become more dynamic and complex.

National security rests on the twin pillars of deterring aggression against the U.S. and its allies—through diplomacy, treaties, and military strength—and reducing the threats posed by others—by stemming and countering the spread of weapons of mass destruction. The Laboratory's national security programs, conducted in the context of the overall national and global security environment, provide science and technology to underpin and support U.S. national security policy.

Livermore's national security programs align directly with the major goal in DOE's Strategic Plan to "support national security, promote international nuclear safety, and reduce the global danger from weapons of mass destruction."

Stockpile Stewardship

As stated by the President and Congress, nuclear deterrence will remain a key component of U.S. national security policy for the foreseeable future. The maintenance of a safe and reliable nuclear stockpile is a supreme national interest. As one of DOE's three national security laboratories, Livermore plays a key role in the Stockpile Stewardship Program for maintaining the nation's nuclear weapons stockpile in the absence of nuclear testing. The accelerated and expanded use of high-performance computing and simulation tools is fundamental to the success of the effort.

Countering the Proliferation and Use of Weapons of Mass Destruction

National security is threatened by the spread and potential use of nuclear, chemical, and biological weapons (collectively referred to as weapons of mass destruction, or WMD). At least 20 countries, some of them hostile to U.S. interests, are suspected of or known to be developing WMD. In addition, WMD materials and technical know-how make terrorist use of such weapons a grave concern. Livermore is addressing the problem of WMD proliferation through a wide spectrum of analysis and technology development activities.

Meeting Other Important National Security Needs

Building on the scientific and technical capabilities needed for the Laboratory's stockpile stewardship and nonproliferation missions, Livermore develops advanced defense technologies for the Department of Defense (DoD) to enhance the effectiveness of U.S. military forces. Livermore's technologies are also increasingly being applied to domestic national security issues—critical infrastructure protection and law enforcement. National laboratories like Livermore can make valuable contributions as DoD and law-enforcement agencies tackle the difficult task of anticipating and responding to shifting threats to U.S. national security.

As a Collaborative Effort. Our work takes place within the context of the national security community—the three DOE national security laboratories, the production plants and the Nevada Test Site, the DoD, and the U.S. intelligence community. With the growing recognition of the vulnerability of the nation's critical infrastructure, Livermore is beginning to address the needs of the Justice Department and other law-enforcement agencies. Many projects involve extensive collaborations with other national laboratories, government agencies, universities, and U.S. industry. We coordinate and integrate our efforts with others to provide the best scientific and technical capabilities to the nation as cost effectively as possible. For a full explanation of our current Laboratory initiatives, see Section 4.

Bolstered by Internal Investments. We target Laboratory Directed Research and Development (LDRD) investments to enhance our ability to meet national security mission objectives. The investments reinforce our core strengths, expand the Laboratory's scientific and technical horizons, and create new capabilities, such as laser cutting for stockpile refurbishment and field-portable biological agent detectors. More generally, LDRD investments help Livermore to explore advanced technologies to meet very challenging, long-term national security needs and to respond promptly to national priorities as they change. Over 90% of the Laboratory's LDRD projects contribute to our national security mission. Livermore's overall LDRD Program is discussed in more detail in Section 3.3.2.

2.1 Stockpile Stewardship

The current course for the nation's nuclear weapons program was set in 1995, when President Clinton announced that the U.S. would pursue a comprehensive nuclear test ban. In making that decision, he reaffirmed the importance of maintaining a safe and

Striving to Meet the Laboratory's Milestones by 2001

Laboratory Activities	Milestones
Section 2 Laboratory Science and Technology—National Security	• The Stockpile Stewardship Program is proceeding as planned, and the stockpile has been certified for the fifth time without the need for nuclear testing.
2.1 Stockpile Stewardship	• The National Ignition Facility building complex is complete, and laser support equipment is being installed.
2.2 Countering the Proliferation and Use of Weapons of Mass Destruction	• The 10-teraops computer for the Accelerated Strategic Computing Initiative is fully operational for stewardship calculations, and Livermore is helping to drive all aspects of high-performance computing.
2.3 Meeting Other National Security Needs	• The Laboratory is providing technology and capabilities to protect the U.S. from nuclear, chemical, biological and other emerging threats to national security.

reliable U.S. nuclear stockpile. Subsequently, the President directed necessary programmatic activities to ensure stockpile safety and reliability in the absence of nuclear testing. The Stockpile Stewardship Program was developed in response to this directive, and, in 1996, the President signed the Comprehensive Test Ban Treaty.

The DOE Office of Defense Programs (DP) is leading its three national security laboratories, the Nevada Test Site, and the production facilities that are part of the weapons complex in the execution of the Stockpile Stewardship Program. This program is designed to ensure the safety and reliability of the U.S. nuclear weapon stockpile in an era of no nuclear testing, no new weapon development, an aging stockpile of fewer weapons and fewer types of weapons, and a reduced production capacity for refurbishing nuclear weapons. *The Stockpile Stewardship Plan: Second Annual Update (FY 1999)*, issued by the DOE Office of Defense Programs in April 1998, provides an executive overview of the Stockpile Stewardship Program and its detailed implementation plan, referred to as the "Green Book."

Program Priorities and Activities at Livermore.

Livermore's efforts support the five major Stockpile Stewardship Program strategies:

- **Integrated management of the Stockpile Stewardship Program**—to ensure that both the major program elements and the activities at the laboratories and plants are tightly interconnected and focused on program goals.
- **Surveillance of the stockpile**—including efforts to better predict aging phenomena sufficiently far in advance that refurbishment of components can be accomplished in a production complex having limited capacity.
- **Assessment of stockpile issues and certification of required changes to the stockpile**—using detailed component-level experiments and sophisticated computational simulations.
- **Refurbishment of stockpile components**—in a flexible, cost-efficient, and environmentally sound fashion.
- **Production of tritium**—on a time scale consistent with stockpile needs.

Priorities for stockpile stewardship activities at the Laboratory are established through consideration of integrated program goals—both Green Book priorities and risks to the overall program if specific activities are less than fully supported. Livermore's integrated priorities, highest first, are:

- **To keep the current stockpile safe, secure, and reliable.** This involves projects such as the W87 Life Extension Program, surveillance, and baselining of the current stockpile systems to support Annual Certification and Dual Revalidation. In general, these activities require full support of the core computing program, physical databases, experiments (including subcritical experiments using plutonium), and the

DOE weapons complex's current suite of facilities.

• **To accelerate development of the advanced experimental and computational capabilities** needed to resolve complex stockpile issues. Major activities include laboratory, industry, and university efforts to develop high-performance computing platforms and applications (Accelerated Strategic Computing Initiative), construction of the National Ignition Facility, and development of advanced radiography technologies and facilities for primary high-explosive experiments.

• **To further develop the underlying science and technology** critical to future stockpile certification. To understand the performance and aging characteristics of nuclear weapons, we need state-of-the-art theory, modeling, and experiments on materials and detailed atomic and nuclear processes.

• **To develop production technologies** for use when the current stockpiled systems must be refurbished or replaced.

The Growing Challenge.

Significant challenges lie ahead because the demands on the program will grow as weapons in the enduring stockpile continue to age. Weapons in the U.S. nuclear stockpile are now older on average than they have ever been. Stockpile problems must be anticipated or detected and then evaluated and resolved without nuclear testing. Existing warheads and weapon systems will have to be refurbished to extend stockpile lifetimes and to meet future military requirements. At the same time, the reservoir of nuclear test and design experience at the laboratories continues to diminish as staff retire. This experience base—and the emerging new tools needed to resolve stockpile issues—must be passed on to the next generation of stockpile stewards.

Successful execution of Livermore's program responsibilities presents many technical and management challenges. The technical demands of the program are significant—many aspects of the required science and technology are at the leading edge of what is possible. We must proceed expeditiously with the program so that enhanced capabilities will be available to deal with difficult stockpile issues, which could arise at any time. These enhanced capabilities will be developed by scientists and engineers with nuclear weapons design and testing experience working with and training the next generation of stockpile stewards. Management challenges stem from the need to both integrate and balance the many elements of the program while working within tight budget constraints.

Managers are also responsible for ensuring that expertise in all aspects of nuclear weapon science and engineering remains high, with particular attention to workforce recruiting, effective on-the-job training, and retention of highly qualified scientific and technical personnel. Workforce recruiting benefits from the Laboratory's LDRD Program (Section 3.3.2), various ties to universities (Section 3.4.3), and the Science and Technology Education Program (Section 3.4.4). These efforts help to attract high-caliber scientists and engineers and develop a future workforce to work on challenging national security problems.

2.1.1 Integrated Program Management and Implementation

Situation and Issues

Integrated program management and implementation are critical to the success of the Stockpile Stewardship Program. The major program elements are tightly interconnected, as are the activities of the three laboratories, the production plants, and the Nevada Test Site. DOE's detailed implementation plan, the Green Book, undergoes annual revision. It specifies roles and responsibilities within the program and defines the capabilities needed for stockpile stewardship without nuclear testing. The plan integrates surveillance, assessment, and life-extension design and manufacturing activities for each weapon system, and (to the extent possible) time-phases all activities to balance the workload. Program integration efforts also include formal processes with the Department of Defense (DoD) for coordinating assessments of stockpile performance and modifications.

Program Thrusts

Annual Certification and Dual Revalidation. Livermore is a key participant in formal review processes for certification of weapon safety and reliability—the Annual Certification of the stockpile for the President and Dual Revalidation. Annual Certification is based on technical evaluations made by the laboratories and on advice from the three laboratory directors, the Commander in Chief of the Strategic Command, and the Nuclear Weapons Council. To prepare for certification, we collect, review, and integrate all available information about each stockpile weapon system, including physics, engineering, chemistry, and materials science data. This work is subjected to rigorous, in-depth intralaboratory review and to expert external review.

In addition to Annual Certification, the DOE has been conducting a Dual Revalidation of the W76 SLBM warhead. It is a process to thoroughly examine over a two- to three-year period the warhead design. We are also establishing with DoD new procedures for conducting life-extension refurbishment programs.

Improved Program Alignment and Integration. For the Stockpile Stewardship Program to succeed, it is crucial that the activities at the three laboratories, the Nevada Test Site (NTS), and the production facilities be a unified effort with integrated goals, milestones, and schedules. To this end in FY 1999, the Deputy Assistant Secretary for Defense Programs, Defense Sciences/Simulations and Developments (DP-10), led an intense series of planning sessions that recast major elements of the Stockpile Stewardship Program into a set of activities that make evident the program integration, establish more clearly the program goals and budget priorities, and help to identify program risks if there are budget shortfalls. The integrated program activities include:

- **Campaigns.** Campaigns are focused, technically challenging, multifunctional efforts that address critical capabilities needed to achieve certification of stockpiled weapons. They have definitive milestones and specific end dates. The twelve campaigns, which integrate the efforts of the three laboratories and the Nevada Test Site, are discussed below.
- **Direct Stockpile Work.** Direct stockpile work includes activities that directly apply scientific understanding and engineering development capabilities to the assessment, refurbishment, and certification of the weapons stockpile. This effort includes weapon maintenance, comprehensive surveillance, assessment and certification, supporting research and development, and scheduled weapon refurbishments. It also includes other stockpile commitments, such as dismantlement and information archiving.
- **Required Technical Base and Facilities.** Adequate support for scientific and technical activities required to develop and maintain intellectual competencies and capabilities is an important part of the overall program. This effort includes assuring that the infrastructure and facilities are operational.
- **Construction.** The overall program includes construction of major facilities such as the National Ignition Facility (NIF) at Livermore and the Dual-Axis Radiographic Hydrodynamic Test (DARHT) facility at Los Alamos. It also includes $100 million per year for line-item construction of other projects at the laboratories and NTS (each facility not to exceed $100 million in cost).

2.1.2 Stockpile Stewardship Campaigns

Situation and Issues

The Stockpile Stewardship Program campaigns integrate experiments, simulation development, and assessment activities and focus these efforts on achieving specific needed capabilities. Twelve campaigns are being pursued to strengthen confidence in future judgments pertaining to weapons certification and decisions about weapon refurbishment. Each campaign is designed to achieve in 2005 a quantifiable end-state associated with a specific stockpile stewardship goal. As they progress toward their end states, the campaigns are to achieve scheduled interim objectives relevant to stockpile needs. For each campaign, the resource needs have been determined together with an assessment of program risks if funding is not adequate. In addition, a set of cross connections with other elements of the program has been identified.

Program Thrusts

The twelve campaigns and their goals are listed. There are no “lead laboratory” assignments for the campaigns. Rather, multilaboratory teams work together to focus and optimize their combined resources to achieve mutual goals. Livermore’s role in each campaign varies, and our major contributions are highlighted in Table 2-1.

Campaign 1: Primary Certification 2005. This campaign focuses on developing and implementing the tools required to certify the performance and safety of any rebuilt or aged primary. Primary performance must be understood within a certain margin of error. As part of the campaign, specific intermediate objectives include:

- Archiving and evaluation of NTS nuclear event data.
- Validation of a high-explosives model.
- Evaluation of rebuilt primaries.
- Development of a high-fidelity-physics, full-primary-burn simulation.
- Development of a pit material equation-of-state (EOS) strength model.
- Development of a self-consistent boost model.
- Evaluation of integral hydrodynamics experiments.

Campaign 2: Dynamic Materials Properties. The goal of this campaign is to produce complete, accurate, and experimentally validated models that describe the behavior of materials essential to primary performance. The focus is on determining the equation of state and constitutive properties of plutonium (e.g., strength, spall, ejecta) as well as organic materials and deuterium–tritium gas mixtures. Understanding the dynamic properties of these materials is central to almost all aspects of stockpile stewardship.

Campaign 3: Advanced Radiography 2005. Campaign 3 aims to provide three-dimensional dynamic radiographic images of imploding surrogate primaries as well as the associated analytical capability applicable to the certification of rebuilt primaries. After nuclear testing, advanced radiography is the most important experimental tool that we have to maintain an aging nuclear stockpile. This campaign includes completing and operating the DARHT facility, developing advanced simulation and analysis capabilities, and providing a technical basis for determining the next step on the path to more advanced radiographic capabilities.

Campaign 4: Secondary Certification and Nuclear System Margins 2005. This campaign will examine the performance of secondaries to identify the minimum factors necessary to produce a militarily effective weapon. The objectives of this campaign include (1) developing a validated predictive computational capability for each system in the stockpile; (2) quantifying our understanding and simulation of primary radiation emission, case dynamics, and energy flow; and (3) determining the

Table 2-1. Livermore contributions to the DOE Defense Program Campaigns.

Campaign	Major Livermore Technical Efforts
1. Primary Certification	• High-fidelity modeling and experiments with Plutonium at NTS (JASPER gas gun and subcriticals) and in the lab, with high explosives at the High-Explosives Applications Facility (HEAF) and Site 300 and with hydrotests at the Flash X-Ray/Contained Firing Facility and DARHT; calculational model development.
2. Dynamic Materials	• Subcritical and gas-gun experiments (Pu); HE experiments at HEAF and Site 300 ; NIF experiments (deuterium and tritium EOS); model development.
3. Advanced Radiography	• Linear induction accelerator (LIA) work for DARHT-2; lead for LIA technology demonstration facility; materials research.
4. Secondary Certification	• Opacity, transport, and interaction experiments at Omega and NIF; physics model development.
5. Enhanced Surety	• Development of advanced initiation, safing, optical, and high-explosives technologies.
6. System Certification	• Experiments to validate models; system-level confirmatory experiments.
7. Hostile Environments	• Nuclear weapon outputs and environments; weapon vulnerability and hardness.
8. Material Lifetimes	• Aging (and accelerated aging) of pits, canned subassemblies, and high explosives; lab experiments; modeling.
9. Production Realization	• Development of materials and production process technologies.
10. ICF/Ignition	• NIF construction and operation; target design and fabrication; experiments and diagnostics.
11. ASCI	• Applications development; data visualization; platform integration; validation and verification.
12. Weapon Baselining	• Design calculations and data archiving.

performance of nominal, aged, and rebuilt secondaries. In the past, our less-than-complete understanding of these issues required nuclear tests to establish performance "margins." Without such tests, aging and remanufacturing issues require a predictive capability.

Campaign 5: Enhanced Surety Solutions for Stockpile Refurbishment. The goal of this campaign is to increase nuclear safety and surety. Main efforts include developing advanced capabilities in micro, optical, and solid-state technologies that improve nuclear warhead safety as well as enhancing use-control and use-denial technologies. A critical factor is to qualify surety solutions for the planned refurbishments of the W76 and W80 warheads while maintaining flexibility to respond to surprises encountered during refurbishment.

Campaign 6: Weapon System Engineering Certification. The intent of this campaign is to establish engineering certification methods that quantify performance and uncertainties of weapon systems at a reduced cost. Predictive engineering computational models will be developed and validated through fewer, smarter, system-level confirmatory experiments. The goal by 2005 is to double the information gained from each fielded experiment so that we can increase weapons understanding while we reduce the number and associated costs of tests.

Campaign 7: Certification in Hostile Environments. The goal of this campaign is to develop certification tools and microelectronics technologies to ensure that refurbished weapons meet stockpile-to-target-sequence (STS) requirements for hostile environments. This campaign has two major thrust areas: (1) the generation of hostile environments by nuclear weapons and (2) the response of nuclear weapons in hostile environments. Technical objectives include developing a suite of validated computational tools for radiation-hardened design and certification, re-evaluating nuclear weapon hostile environments, and demonstrating certification technologies on the W76 life-extension program. The development of computational models will reduce reliance on laboratory tests.

Campaign 8: Lifetime Assessments. This campaign will provide a validated basis to certify aged components, specify when components must be replaced, and determine when new manufacturing facilities are needed. It will provide the first science-based assessment of pit, high explosive, organic material, and canned subassembly lifetimes by furnishing quantitative bases for future stockpile life-extension programs (SLEPs). One of the goals is to minimize or eliminate unnecessary refurbishment costs.

Campaign 9: Integrated Product Realization Environment. This campaign will provide the capability to deliver qualified SLEP refurbishment products upon demand with zero manufacturing defects and in half the time and cost compared to what we could deliver in 1998. For this campaign to succeed, a successful partnership between the weapons laboratories and production plants is essential.

Campaign 10: Inertial Confinement Fusion (ICF)/Ignition. The long-term goal of this campaign is to conduct ICF ignition physics implosions and to enhance experimental capabilities for stewardship. To attain these goals, several intermediate steps are required, including (1) demonstrating required drive symmetry and laser pulse shape for ignition; (2) designing, developing, and fabricating ignition targets; and (3) building NIF target diagnostics.

Campaign 11: Accelerated Strategic Computing Initiative (ASCI). This campaign focuses on the shift from nuclear-test-based methods to computation-based methods to certify the safety, reliability, and security of the stockpile. Critical near-term milestones include the development of prototype three-dimensional primary and secondary simulations and abnormal environment thermal assessments.

Campaign 12: Weapon System Baselining. The mission of this campaign is to develop a modern certification basis for each weapon system in the stockpile. Activities will focus on exploiting past and current experimental activities, validated design-assessment codes, and nuclear test archives. The goal is to establish a peer-reviewed baseline understanding and model of weapon system performance and safety.

Laboratory Initiatives

- Accelerated Strategic Computing Initiative (DP)
- Two-Stage Light-Gas Gun—JASPER Facility (DP)

2.1.3 Direct Stockpile Work

Direct stockpile work includes weapon maintenance, comprehensive surveillance, assessment and certification, supporting research and development, and scheduled weapon refurbishments. It also includes other stockpile commitments, such as dismantlement and information archiving.

Situation and Issues

Livermore-Designed Weapons. Livermore is the design laboratory for four nuclear weapon systems in the stockpile: the W87 and W62 ICBM warheads, the B83 bomb, and the W84 cruise missile warhead. These warheads are expected to remain in the stockpile well past their originally anticipated lifetimes; the W62 is already doing that. We have special responsibilities for the surveillance of these systems, assessments of their performance and safety, and their refurbishment. We also have broader responsibilities to develop assessment capabilities, technologies, and processes that contribute to maintaining the safety and reliability of all stockpiled weapons.

Assessments. Assessments provide the foundation for formal certification of stockpile performance and refurbishment decisions. The Stockpile Stewardship Program includes a comprehensive set of activities to address issues that arise from stockpile surveillance and to evaluate the significance of observed and predicted aging processes. When modifications are deemed necessary, we must assess options for refurbishing or replacing specific warhead components as well as for new production and fabrication processes and materials. Modification actions must then be certified.

Assessments must be based on scientific and engineering demonstrations to be credible. In the absence of nuclear testing, we rely on data from past nuclear tests as a benchmark, component-level experiments and demonstrations, and advanced simulations for an integrated assessment of weapon performance and safety. This approach has enabled us to successfully address stockpile issues that have emerged to date. However, as the stockpile ages, we anticipate that more difficult assessment issues will arise. In addition, it is possible that, as in past cases, design and production flaws will be discovered in systems that have been in the stockpile for some time.

Stockpile Surveillance. With fewer types of weapons in the stockpile and reduced capabilities and capacity in the production complex, we must become more proficient at early detection and identification of precursors of potential problems so that we have adequate time for thorough evaluation and action before problems affect stockpile safety or reliability. As noted, our stockpile surveillance efforts focus on Livermore designs in the stockpile. These efforts include developing improved monitoring capabilities and building the scientific base to better understand aging effects in all stockpiled weapons (see Campaign 8, p. 26). With a better understanding of aging, our stockpile surveillance can be more predictive, making possible systematic refurbishment and preventative maintenance activities to correct developing problems.

Weapon Refurbishment. Weapon refurbishment—needed because weapon components degrade over time—is a particularly demanding challenge because we cannot rebuild many weapons components exactly as they were manufactured. In many cases, the materials or the manufacturing processes originally used are no longer available or are environmentally unacceptable. Production quality assurance must be provided by new assessment and certification processes that do not include nuclear testing.

We are working closely with the production plants to integrate the development of replacement components with the development of new materials and manufacturing processes. To lower costs and environmental impact, refurbishment can make use of modern production technologies and incorporate major technical advances that have occurred since the weapons were first manufactured. We focus on technologies that are flexible and high quality (to provide defect-free production in a capacity-limited complex) and that use modern commercial methods wherever possible.

Program Thrusts

A Strategy to Improve Assessment Capabilities. The expectation that more challenging stockpile issues will arise as weapons continue to age is driving the program's campaign strategy (see Section 2.1.2, above) and investments in more capable experimental facilities (see Section 2.1.4). These investments include the National Ignition Facility (NIF) and the Dual Axis Radiographic Hydrodynamic Test Facility (DARHT). We are also developing greatly enhanced numerical simulation tools through the Accelerated Strategic Computing Initiative (ASCI). Livermore has major responsibilities in the execution of the ASCI program and the construction of the NIF.

W87 Life Extension. A principal program thrust at Livermore is the W87 Life Extension Program (LEP). The objective of the LEP is to enhance the structural integrity of the warhead so that it can remain part of the enduring stockpile beyond the year 2025 and will meet anticipated future requirements for the system. We have completed development activities, which have included flight testing, ground testing, and physics and engineering analyses, and production processes have been certified. The first refurbished unit was completed in February 1999, and the final production unit is scheduled for completion in 2003.

We are also developing comprehensive plans to extend the stockpile life of other Livermore-designed systems. To this end, significant effort is being expended on their surveillance, maintenance, and selective refurbishment.

ADaPT. As part of the Advanced Design and Production Technologies (ADaPT) initiative, the Laboratory is teaming with the plants to develop and provide greatly improved manufacturing technologies for stockpile refurbishment and life extension of weapon systems. We have signed cooperative agreements with Savannah River and Pantex to develop and transfer technologies more efficiently in areas of mutual interest. We are also forging partnerships on production projects with the Y-12 and Kansas City plants, and we are working with TA-55 at Los Alamos on plutonium part-production technologies that reduce cost, hazardous waste generation, and radiation exposure to workers. Livermore is an important part of efforts to develop a coordinated plan to supply new weapons pits as needed for warhead refurbishment. Recent program accomplishments are summarized in DOE Defense Programs' *ADaPT 1998 Annual Report* (UCRL-LR-133443).

One area of continuing interest is the use of an ultrashort-pulsed laser for precision cutting, a technology that earned an R&D 100 Award in 1997. For the Y-12 plant, we have built a production-worthy Laser Cutting Workstation, which was delivered in October 1998 and will have general applicability to several stockpile systems and refurbishment programs. We also demonstrated the laser system as a safe and precise tool for cutting high-explosive materials. The Pantex Plant is very interested in further development of laser cutting for high-explosive applications. In addition, we are working with Pantex to establish a pilot production capability for TATB, the explosive ingredient that, over time, will have to be replaced in stockpiled weapons. Developed by Laboratory researchers, the production process is based on an entirely new synthesis route that avoids producing chlorinated compounds dangerous to Earth's ozone layer.

In addition, to foster greater integration of work throughout the weapons complex, we are developing a complex-wide, secure, high-speed digital network. In effect, it will be a "Secure Internet" with classified information shared on a need-to-know basis. Initial implementation of the system will allow Livermore engineers and designers to have access to "as-built" production, disassembly, and surveillance data from Y-12 and Pantex during W87 life-extension program refurbishment activities.

Enhanced Surveillance. Major efforts are under way to enhance surveillance capabilities. Livermore's contributions to the DP-wide Enhanced Surveillance Program are included in *Enhanced Surveillance Program FY 1998 Accomplishments* (UCRL-LR-132042). For example, we are preparing detailed archives of existing test data, and we are using very modern instrumentation to obtain even more precise physical data on stockpiled weapons. The accumulated information serves as a baseline to identify anomalies in aging weapons as they occur. We are also improving the sensors and techniques for inspecting stockpiled weapons. Furthermore, we are developing a better understanding of how aging alters the physical characteristics of weapon materials and components.

For example, we are making significant progress on improving detection capabilities and computer models of corrosion in nuclear weapons. Understanding the evolution of the gases and materials in a weapon and extrapolating the long-term consequences present challenges to our materials scientists. Working with the production plants, we are using a newly developed technique for sampling evolved gases within stockpile weapons that is extremely efficient and does not require collecting a large gas sample. Livermore researchers also are developing a computer model of the generation, transport, and reaction of materials in aging canned sub-assemblies (CSAs) in weapons. We will be able to use the simulation tool, when it is thoroughly tested and validated, to predict the effective life of CSAs.

In addition, we are greatly improving our understanding of the properties of plutonium. This is a very important issue—we need to understand aging in plutonium and its effect on the performance of an imploding pit of a stockpiled weapon. We are obtaining this information through advances in theoretical modeling and non-nuclear research tools, just recently becoming feasible and increasingly made available through Stockpile Stewardship Program investments. Efforts include various types of laboratory experiments to study the microstructure of plutonium, computer simulations of plutonium at the atomic and molecular scales, and subcritical experiments at the Nevada Test Site. Working with colleagues at Los Alamos, we have also devised a means for carrying out accelerated aging tests that will help us assess the performance of plutonium pits much older than those now in the stockpile.

Laboratory Initiatives

- Advanced Design and Production Technologies Initiative (DP)
- Advanced Surveillance (DP)

2.1.4 Technical Base and New Construction for Stockpile Stewardship

Stockpile Stewardship Program plans include construction of major facilities such as the NIF, line-item projects to build other smaller mission-critical research facilities and upgrade or rehabilitate existing ones, and support for scientific and technical activities that develop and maintain necessary intellectual competencies and capabilities.

Situation and Issues

The Need for NIF. The National Ignition Facility (NIF) is a cornerstone of the Stockpile Stewardship Program. It will be the only facility capable of well-diagnosed experiments to examine fusion ignition and burn and to study the thermonuclear properties of primaries and secondaries in nuclear weapons. Advanced computer models being developed for stockpile stewardship need to be improved and validated by tests in the physical conditions that only the NIF can provide. With the NIF, researchers will have the opportunity to achieve fusion ignition and burn in a controlled laboratory setting (Campaign 10, p. 26). To succeed will be both a remarkable achievement and meaningful indicator that stockpile stewardship is working. Like the design of a nuclear weapon, fusion in the laboratory is an integral experiment that tests the skills and resourcefulness of the physicists and engineers who will be the nation's stockpile stewards in the future. It will measure success in combining advanced simulation and experimental techniques. Success in fusion ignition experiments will also greatly boost the value of the NIF as tool for laboratory experiments to address real stockpile problems.

ASCI and Future Facility Needs. The Accelerated Strategic Computing Initiative (ASCI) is a program to dramatically advance our ability to computationally simulate the performance of an aging stockpile and the conditions affecting weapon safety (Campaign 11, p. 26). The initiative is designed to deliver significant new capabilities at a steady pace in support of stockpile stewardship. To make the needed major advances in weapons science and weapons simulation code technology, Livermore, Los Alamos, and Sandia national laboratories are obtaining from U.S. industry dramatic increases in computer performance and information management. The Laboratory is scheduled to take delivery of a supercomputer capable of 10 trillion operations per second (10 teraops) in 2000. Planned expansion of Livermore's computing power beyond the 10-teraops platform will require a new facility, the Terascale Simulation Facility.

Key Research Facilities at Livermore. Livermore has special responsibilities in the Stockpile Stewardship Program because of our special skills and capabilities and because of unique user facilities that exist at Livermore and must be maintained. In addition to a number of important but smaller science and engineering facilities, these include:

- **The High Explosives Applications Facility (HEAF)** is the most modern facility for high explosives research in the world. HEAF is a center for the study of chemical high explosives. It combines all the capabilities needed to synthesize, formulate, and test new explosive compounds. High explosives can be safely detonated in specially designed vessels in quantities up to 10 kilograms. Experiments are supported by state-of-the-art diagnostic equipment that includes high-speed rotating-mirror streaking and framing cameras, electronic image-converter cameras, optical interference velocimeters, and image-forming x-ray machines.
- **The Flash X-Ray and Contained Firing Facility**, until DARHT is completed, is the most capable hydrodynamic test facility in the world. The Contained Firing Facility, when its construction is completed in FY 2000, will be a 2,700-square-meter indoor explosives testing facility at Site 300 that houses the newly upgraded Flash X-Ray (FXR) machine. The containment addition includes a reinforced firing chamber, a support staging area, and additional diagnostic space for testing up to 60 kilograms of explosive materials. Emissions to the environment will be drastically reduced, and hazardous waste, noise, and blast pressures will be minimized. The facility, now shut down during construction, will be reactivated in FY 2000.
- **The Secure and Open Computing Facilities** meet the Laboratory's programmatic needs and serve as a testbed for development of high-performance computing hardware and software. Livermore Computing maintains two computing facilities, one for classified work (the Secure Computing Facility) and the other for unclassified work (the Facility for Advanced Scalable Computing Technology).
- **The Superblock** houses modern facilities for nuclear materials research and engineering testing. The Plutonium Facility, in particular, is engaged in activities to prepare and monitor accelerated-aging plutonium samples. The facility is also used to prepare plutonium samples for Livermore's subcritical tests, to investigate technologies for remanufacture of plutonium parts in Livermore-designed

weapons, and to conduct other fundamental physics and engineering experiments involving plutonium. In addition, as part of the DOE's nonproliferation efforts, the facility is central to the multilaboratory Plutonium Immobilization Program to develop means for disposing excess U.S. plutonium.

Program Thrusts

A comprehensive summary of Livermore's facility plans and resource requirements is presented in Section 5.2.1. Two major items are:

NIF Construction. Construction is under way at Livermore for the NIF, a facility housing a 192-beam laser and associated experimental capabilities. It will be by far the world's largest laser. Groundbreaking for the facility occurred in May 1997 and NIF conventional facility construction is scheduled for completion at the end of FY 2000. An important milestone was reached with the June 1999 dedication of NIF's 150-ton target chamber and its relocation into the chamber bay.

Procurement of special equipment is under way, building on critically important partnerships forged with U.S. industries to ensure that equipment based on the advanced technologies needed for the NIF can be fabricated to meet operational specifications. In particular, partnerships with industry have been pursued to develop mass-production techniques and assure the production quality of large-aperture, high-precision optical components. Key technology advancements range from methods for rapid growth of superior quality crystals that weigh over 500 pounds (226.8 kilograms) to interferometers that can measure the accuracy of optical surfaces to about the width of an atom.

Terascale Simulation Facility. Expansion of Livermore's computing power beyond the 10-teraops platform will require construction of the Terascale Simulation Facility (TSF). Plans for the TSF have been developed, and a Conceptual Design Report has been approved. Design of the TSF is driven primarily by power and space requirements for future-generation ASCI-scale computers. Between 6 and 8 megawatts are required to run the computer, and cooling needs an additional 4 to 5.5 megawatts. The building will also house the growing staff of computer and physical scientists who support the computers or work on research and development projects such as the Data and Visualization Corridors (DVCs) necessary for assimilating terascale data sets. The construction project is being initiated with a FY 2000 line-item authorization of $8.0 million and requires $20.0 million in FY 2001. The estimated total cost of the facility is $83.5 million and, with timely funding, TSF will be completed late in 2004.

Laboratory Initiatives

- National Ignition Facility (DP)
- Terascale Simulation Facility (DP)

2.2 Countering the Proliferation and Use of Weapons of Mass Destruction

We apply Livermore expertise in nuclear weapons, developed over time through the Laboratory's weapons program and continuing stockpile responsibilities, to the challenge of nuclear nonproliferation. Because the threat of proliferation is not restricted to nuclear weapons, we also build on Livermore's large investment in chemical and biological science to develop technologies and expertise to stem the spread of chemical and biological weapons.

This threat is extremely complex. There are myriad routes to weapons of mass destruction—many different starting materials, material sources, production processes, and deployed weapons. There are also many possible proliferators—threshold countries, rogue states, state-sponsored terrorist groups, domestic terrorists, and even internationally organized criminals and narcotics traffickers. Motives for acquiring and using weapons of mass destruction are similarly wide ranging—from a desire to change the regional military balance, deny access to a strategic area, or alter international policy to extortion, revenge, or hate.

Our principal sponsor is the Department of Energy's Office of Nonproliferation and National Security (NN). Other sponsors include the Department of Defense, various U.S. intelligence agencies, and the Department of Energy's Office of Defense Programs. Our activities are coordinated with and complement the work of other government laboratories and agencies.

We address the problem of weapons proliferation at all stages—prevention, detection and reversal, response, and avoiding surprise. In addition, our Center for Global Security Research brings together the technology and policy communities to explore ways in which technology can enhance national and international security.

2.2.1 Proliferation Prevention and Arms Control

Situation and Issues

The best way to stop nuclear weapons proliferation is at the source through control of weapons-usable nuclear materials. The security of these materials in Russia is of particular concern, given that country's dire economic straits and its inability to support the Soviet nuclear infrastructure. In contrast, chemical and biological weapons proliferation is much more difficult to control at the source because the materials and technologies for such weapons are ubiquitous and often have legitimate uses.

For all types of weapons of mass destruction, arms control agreements—and verified compliance with the agreements—are key components to preventing proliferation and enhancing regional, national, and international security. Livermore has provided technical and analytical support to U.S. arms control efforts for more than 40 years. We have contributed to the SALT treaties; the Limited, Threshold, and Comprehensive Test Ban treaties; the START agreements; and the Chemical and Biological Weapons conventions.

Program Thrusts

Arms Control and Treaty Monitoring. Livermore assesses for the U.S. government the impact of proposed treaty provisions in terms of U.S. ability to monitor other countries and to protect sensitive information during foreign inspections of U.S. facilities. We also develop monitoring technologies and participate in field trials to prepare for inspections in the U.S. and abroad. We are currently involved in technical activities to prepare for the entry into force of the Comprehensive Test Ban Treaty (CTBT) and for future arms reduction agreements limiting nuclear warheads.

We are responding to the technical challenge of monitoring compliance with the CTBT. The process requires gathering and analyzing regional seismic signals. Because of the complicated structure of the Earth's crust through which regional seismic waves travel, extensive seismic R&D is required. Livermore is responsible for the R&D needed to allow the U.S. to monitor the Middle East, North Africa, the former Soviet Union, and the oceans. We are mapping regional variations in wave propagation and developing corrections to processing algorithms so that event detection, location, and identification are accurate and precise and so that uncertainties are characterized properly.

Wherever possible, we use data from known events (i.e., ground truth). For regions where we do not have physical access (e.g., Iran and Iraq), we use data from seismographic stations near the area and then identify events by means of independent phase amplitudes. Using clustering analysis, we can identify events that come from a specific location, which may then be correlated using overhead imagery (SPOT or LANDSAT) with, for example, an active mining operation. In regions where we have access (e.g., Jordan and Israel), we are pursuing collaborative in-country experiments. In May 1998, Livermore scientists installed three monitoring stations in Jordan. We also contribute to preparing for the CTBT through participation in U.S. delegations to the CTBT Preparatory Committee (PrepCom), development and demonstration of monitoring methods for on-site inspections (OSIs), and sponsorship of and participation in OSI exercises to prepare for inspections at home and abroad.

Protection of Nuclear Materials. We participate in three programs to improve the control of nuclear materials worldwide—Material Protection Control and Accounting (MPC&A), Second Line of Defense, and Counter-Nuclear Smuggling. The DOE's MPC&A program focuses on securing weapons-usable nuclear materials in the former Soviet Union (FSU). We lead activities at five of the 50-plus MPC&A sites: Krasnoyarsk-45, Sverdlovsk-44, Bochvar, Automatics, and Chelyabinsk-70. This year, we completed the physical protection and computer accounting upgrades at the Pulsed Research Reactor Facility at Chelyabinsk-70, and a commissioning ceremony was held in May 1998. We also work with the Northern and Pacific fleets of the Russian Navy and the Murmansk Shipping Company to enhance the protection of fresh, highly enriched reactor fuel for their nuclear-powered vessels. This work involves direct interactions with the Russian Ministry of Defense to characterize the sites, define the necessary improvements, and then implement the upgrades.

The Second Line of Defense and Counter-Nuclear Smuggling programs address the need to detect and intercept illicit traffic in nuclear materials. The new Second Line of Defense program focuses on Russian borders, while the counter-nuclear smuggling activities focus on other international borders. Livermore's capabilities in radiation detection and forensic science are central to these efforts. In the Second Line of Defense, we are working with Russian Customs to equip border crossings with radiation detection equipment, beginning first with a seaport on the Caspian Sea. We are also collaborating with Russian Customs in a global assessment of nuclear smuggling threats, with particular focus on international airports, to identify needs and define the role of technology. For the counter-nuclear smuggling effort, we are developing radiation detection instruments that can identify nuclear materials at low levels and in the presence of spectral clutter and/or shielding.

Plutonium Disposition. Both the U.S. and Russia have large quantities of surplus nuclear materials. For the disposition of plutonium from dismantled U.S. nuclear weapons, we are continuing the development and demonstration of systems to bisect pits, remove the plutonium, and convert the plutonium metal into plutonium oxide suitable for either immobilization or mixed oxide (MOX) fuel for reactor burning. The pit bisector is a chipless method for opening weapons pits to permit removal of the plutonium. The hydride/oxidation (HYDOX) module is a dry process for converting plutonium metal to plutonium oxide. This past year, we completed bisector demonstrations on seven U.S. pit types and upgraded the bisector that will be used by Los Alamos as part of the Pit Disassembly and Conversion (PD&C) demonstration line. For the HYDOX process, we demonstrated a hydride-nitride cycle approach that is faster and uses only a small amount of hydrogen, significantly enhancing process safety and decreasing the number of HYDOX systems required in the PD&C plant.

Livermore is the lead laboratory for DOE's multilaboratory program to immobilize excess U.S. plutonium. With DOE's selection of titanate-based ceramic over lanthanide borosilicate glass as the preferred waste form, we have moved on to detailed testing for repository acceptance and development of the ceramic process line. We are also performing a design-only conceptual design review, which should lead to construction design in FY 2000 and plant operation in 2006. We also lead DOE's efforts to engage the Russians in plutonium immobilization activities that parallel those in the U.S. The objective is to develop, by 2004, an in-country capability for industrial-scale stabilization and immobilization of Russian impure excess weapons plutonium at one or more of the three plutonium processing sites in Russia. R&D for this project builds on the work done for the U.S. plutonium immobilization program. Contracts were let this year with Russian institutes for R&D on glass and ceramic immobilization forms, and we are negotiating with Russian industrial sites for feasibility studies on alternate plutonium disposition methods.

Control of Weapons-Related Expertise. Proliferation prevention also requires the protection of weapons-related knowledge and expertise. Through the Initiatives for Proliferation Prevention (IPP), the International Science and Technology Center (ISTC), and the Science and Technology Center of Ukraine (STSU), we are working with former Soviet weapons scientists to help them develop self-sustaining commercial applications for their skills and thereby obviate the need for them to market their skills to potential proliferants or rogue states. Technologies developed through these programs include superplastic forming processes for aluminum and alloy compositions, high-efficiency low-cost absorbants for environmental cleanup, and ceramic and diamond material processing. We are collaborating on more than 50 such projects, which support approximately 1,000 former Soviet weapons scientists.

Laboratory Initiatives

- Activities with Russia and the NIS (NN)
- Support of Arms Reduction Treaties (NN)
- Environmental Security (NN)

2.2.2 Proliferation Detection and Defense Systems

Situation and Issues

In order to reverse weapons proliferation, we must first detect and identify weapons-related activities. Weapons development, testing, and production all have unique indicators that, if detected and characterized, can provide clues to the intent and status of a country's weapons program. Because the clues are fragmentary and often ambiguous, we must tap many sources of information—chemical analyses of water, soil, and air; satellite imagery; industrial activity; import records; material and personnel movement—to assemble a reliable overall picture. By analyzing proliferators' weapons of mass destruction (WMD) production capabilities, we can identify likely chemical signatures of proliferation activity, which we can then use as a basis for developing various sensing and detection instruments. In addition, working with the military services, we are developing sensor networks and other tools to help protect forces in the field.

Program Thrusts

Counterproliferation Analysis. We provide U.S. policymakers and military planners with tools and information needed to evaluate the implications of various counterproliferation actions. For example, we have developed a powerful and comprehensive system for analyzing weapons proliferation activities of foreign countries, identifying critical facilities, and evaluating consequences of possible interdiction options. With the Counterproliferation Analysis and Planning System (CAPS), we do end-to-end process analysis of proliferators' WMD production capabilities, assess interdiction options and corresponding consequences, and identify detectable signatures of proliferation activity.

Remote Monitoring. Remote detection and identification of trace amounts of chemicals released into the atmosphere are extremely difficult problems that require significant advances in detection instrumentation and data analysis techniques. Instruments under development at Livermore include an advanced mid-infrared lidar system for active detection of chemical effluents and a passive hyperspectral imaging instrument. Both our multi-wavelength differential absorption lidar (DIAL) and our hyperspectral infrared imaging spectrometer (HIRIS) were successfully field tested this past year. Work to date indicates that the combination of a passive long-wave infrared imaging system (like HIRIS) and a mid-wave infrared active lidar (like DIAL) would provide a system with significantly more utility than either system alone. We are pursuing the development of such a hybrid system to exploit the advantages of passive imaging systems and the enhanced sensitivity of active interrogation.

The value of new instruments such as HIRIS depends, in large part, on how well the data can be incorporated into expert assessments. Livermore is developing prototype tools to assist analysts in interpreting multi- and hyperspectral data in conjunction with other available data sources. In one project, we are integrating our Counterproliferation Analysis and Planning System (CAPS) with remote sensing data from HIRIS and meteorological data and plume calculations by the Atmospheric Release Advisory Capability (ARAC). These efforts leverage knowledge gained from established Laboratory programs in intelligence analysis, chemical process modeling, atmospheric science, and sensor development.

Tactical Systems. More than 20 years of experience in conflict simulation have culminated in the Joint Conflict and Tactical Simulation (JCATS). JCATS allows training, planning, and analysis from the campaign level on a 600-square-kilometer terrain to individuals operating inside a multistory building. This year, we completely reworked JCATS into a modernized architecture in C++ language with an object-oriented database. We pushed the boundaries of C++ capabilities to allow the models to interact at the level needed to provide for JCATS' unique feature of dynamic aggregation and disaggregation. JCATS is used by more than 50 organizations, including the Joint Warfighting Center, most of the U.S. military commands, and some of the military services.

In a project for DoD's Joint Project Office for Bio-Defense, we are collaborating with Los Alamos to develop a detection and communication system to provide U.S. troops in the field with early warning of a biological attack. The Joint Biological Remote Early Warning System (JBREWS) combines a flexible network of commercially available sensors with the military's communications assets. It is portable and flexibly deployable to any and all locations where U.S. troops are deployed. In summer 1998, we participated in a DoD Advanced Concept Technology Demonstration (ACTD) where JBREWS successfully demonstrated the operation of particle sensors, communications, data processing, and the detection algorithm.

Ballistic Missile Lethality. We analyze the capability of various interceptor systems to defend against and negate the effects of ballistic-missile-delivered WMD. Through a combination of calculation and experiment, we analyze the damage and probability of kill resulting from given impacts of a kinetic-energy interceptor onto an incoming ballistic missile. This year, we initiated a project to investigate the use of remote sensing instruments in ballistic missile defense. Our goal is to develop real-time characterization of impact and debris to determine the type of incoming warhead (conventional high explosive or WMD) and provide battle commanders with a rapid identification of enemy warheads and source terms of onboard chemical or biological agents.

2.2.3 Counterterrorism and Incident Response

Situation and Issues

Despite all attempts to prevent the spread of weapons of mass destruction and to reverse proliferant weapon programs, we must also be prepared to respond to the threatened or actual use of a nuclear, chemical, or biological weapon. Terrorists are exhibiting an increasing desire to cause indiscriminate mass casualties (witness the 1998 bombings of the U.S. embassies in Africa), and thus terrorist use of weapons of mass destruction is a growing threat. Livermore expertise in nuclear detection, explosives, remote sensing, and other technologies is being applied to counter this threat. Working with other U.S. government agencies and first-responder organizations, we are developing capabilities for threat assessment and effects prediction, techniques for disabling terrorist devices, and technologies for the early detection and identification of nuclear, chemical, and biological weapons agents.

Program Thrusts

Incident Response. We are a key participant in the national Joint Technical Operations Team (the successor to the Nuclear Emergency Search Team), the Accident Response Group, the Radiological Assistance Program, and the Federal Radiological Management Assistance Capability. Our Threat Credibility Assessment Program provides technical, operational, and behavioral evaluations of weapons-of-mass-destruction extortion threats. Upon request of the FBI, we also furnish emergency response personnel and equipment for such high-visibility events as the Olympic Games and provide forensic analyses beyond the capabilities of the Bureau's own laboratories.

Biodetection. The DOE's Chemical and Biological Weapons Nonproliferation Program addresses the threat posed by chemical and biowarfare agents. At Livermore, we focus on bioinformatics, detector development, systems analysis, decontamination, and plume modeling. Our bioinformatics research contributes to the fundamental understanding of the biological threat organisms that is needed for optimum incident response and eventual assigning of attribution. This information will be used to increase the robustness of our pathogen detection assays, with the ultimate goal of making detectors that are immune to the potential cloaking effects of genetic engineering.

Laboratory researchers have developed unique miniature instruments, such as a miniature flow cytometer and a miniature polymerase chain reaction (PCR) thermal cycler that are greatly improving biological agent detection. At Department of Defense-sponsored biological agent detector field trials in 1996, 1997, and 1998, the performance of our devices matched or exceeded the best performing commercial devices available. In 1998, based on this outstanding performance, the Naval Medical Research Institute (NMRI) Biological Response Unit selected our automated ten-chamber PCR device for deployment to the Middle East. We built and delivered two more ten-chamber instruments, one to NMRI and the other to the U.S. Army Medical Research Institute of Infectious Diseases (USAMRID). In 1999, we reported a breakthrough in PCR analysis, namely routine 7-minute detection of key biological agents. This breakthrough was achieved through extreme miniaturization of the thermal cycling chamber. Instruments with multiple PCR chambers are currently being prototyped.

Counterterrorism. Because urban first responders and local emergency managers play a critical role in countering and mitigating acts of WMD terrorism within the U.S., we launched an important new initiative directed at civilian, urban counterterrorism needs. Together with Los Alamos, we are working with the emergency planning organizations in Los Angeles County and New York City to understand the needs of urban first responders for WMD capabilities and to identify capabilities within the national laboratories that could help in urban WMD emergency response. We have participated in a major exercise in each city and are now a regular member of the Los Angeles emergency planning group. Even in the early stages of this initiative, it is apparent that technology resident at Livermore and Los Alamos can be quickly applied to counterterrorism problems in an urban environment.

Forensic Science. Our Forensic Science Center continues to develop new technologies to detect, characterize, and attribute the source of weapons materials. We also develop microanalytical forensic techniques, new field instruments, and sample collection techniques for use by federal and local law enforcement agencies (see Section 2.3). This past year, the FBI named the Forensic Science Center as its west-coast support laboratory. In May 1999, we delivered a portable (55-pound) gas chromatograph–mass spectrometer (GC–MS) to the FBI; this instrument has all the sensitivity, selectivity, and accuracy of instruments that fill entire laboratories.

Laboratory Initiative

- Counterterrorism (NN)

2.2.4 International Assessments

Situation and Issues

A formal program in international assessments was established at Livermore in 1965 to analyze the Soviet nuclear threat and, shortly thereafter, the Chinese threat for the U.S. intelligence community. Since then, we have expanded our efforts to include nuclear as well as chemical and biological proliferation in smaller nations, rogue states, and terrorist groups. Of particular concern are the activities of threshold states (countries thought to be able to develop or produce nuclear weapons within a few years or less). We also review export license requests for the U.S. Department of Commerce and provide technical support and assistance to the U.S. intelligence community.

Program Thrusts

We assess nuclear proliferation risks in key areas of the world. Some potential proliferators have had antagonistic relations with the U.S. for years, and many are located in politically unstable regions of the world. Nuclear programs in South Asia and North Korea are examples of grave nuclear proliferation concerns.

We also analyze the status of nuclear weapons and weapon materials in the declared nuclear states. Ongoing efforts focus on issues affecting the long-term maintenance of foreign nuclear weapons stockpiles. This research helps to elucidate important differences between the specific set of U.S. technical stockpile stewardship issues and the stockpile issues affecting other declared nuclear weapon states. Careful accounting for these differences can promote better understanding of activities observed at foreign test sites. This improved understanding can help resolve questions about these foreign nuclear weapons programs and about their governments' commitment to international arms-control initiatives.

In addition, we conduct assessments related to foreign countries' chemical and biological weapons programs. Our assessments of foreign weapons programs provide important input to policy makers and diplomats as they develop strategies for U.S. response to events affecting national and international security.

Laboratory Initiative

- Sensitive Compartmented Information Facility (NN)

2.2.5 Center for Global Security Research

Situation and Issues

Technical issues comprise only a portion of the nonproliferation and counterterrorism picture. Our Center for Global Security Research (CGSR) brings together technologists and policy people to examine ways in which technology can enhance national and international security.

Program Thrusts

The center focuses on four areas of particular interest:

- Managing, controlling, and reducing the threats associated with weapons of mass destruction.
- Evaluating the security implications of emerging technologies.
- Anticipating and managing threats to national and international security.
- Assessing future roles of the military.

In its first two years, the CGSR has teamed with other centers on a number of instances, with productive and significant results. Recent workshop topics have included the future of nuclear deterrence (with the National Defense University), implications of the revolution in biotechnology on the Biological Weapons Convention (with the Monterey Institute for International Studies), and ways to increase the proliferation resistance of the nuclear fuel cycle. The center also supports CGSR fellows to study such complex issues as why countries choose not to develop nuclear weapons, humanitarian demining, and U.S. policies for dealing with the threat of ballistic missile proliferation. In selecting workshop and study topics, the center looks for critical security issues that have generally been neglected, especially those concerning the interrelationship of policy and technology by other institutes and organizations (including the U.S. government).

2.3 Meeting Other National Security Needs

Livermore works with the Department of Defense (DoD) and other government agencies to leverage the Laboratory's capabilities and provide long-term research and development support to meet current and future national security needs.

2.3.1 Department of Defense

Situation and Issues

The focus of future U.S. defense efforts has been the subject of a number of studies completed by the Joint Chiefs of Staff and the military services the Quadrennial Defense Review, and the Alternate Force Structure Assessment. The vision emerging from these studies is of a U.S. "military of the future" that exploits technological superiority to win quickly, decisively, and with minimum casualties on all sides.

Livermore has experience and expertise in many areas of science and technology directly relevant to this military of the future, including ballistic missile defense, solid-state lasers, armor/anti-armor materials and munitions, conflict simulation, micro- and nanofabrication, remote sensing, and sensors and sensor networks. In addition, many of the Laboratory's proliferation detection tools and technologies are also applicable to battlefield situations. Livermore also has a long-standing history of collaboration with the DoD. For example, for more than a decade, we have been engaged in a DOE–DoD advanced conventional munitions technologies program for which we have developed new energetic materials and computer tools for design and analysis of munitions. One result of this partnership is the Livermore-developed high explosive, LX-14, now used in the TOW and Hellfire missiles. Our CHEETAH code is also widely used by the DoD to predict the performance of propellants and explosives and to evaluate formulations of new energetic materials.

Program Thrusts

The DOE laboratories are working to establish ways to further increase the effectiveness of the support provided to the DoD. For example, in response to FY 1998 Congressional authorization language, we helped prepare a pilot proposal for a hardened and deeply buried target defeat program that would facilitate effective teaming between the DOE laboratories, DoD, and defense industry to meet important military needs in this area.

By applying Livermore's special expertise, we contribute to meeting identified DoD needs in four areas:

• **Quick and Decisive Military Operations.** The U.S. military's ability to conduct operations quickly and decisively depends heavily on advanced sensors, information technologies, and predictive meteorology capabilities (e.g., the use of Livermore's Atmospheric Release Advisory Capability, ARAC, as discussed in Section 3.1.3). Livermore is using its demonstrated strengths and capabilities to pursue innovations in each of these areas.

• **Precision Weapon Systems.** Livermore contributes its expertise in energetic materials, advanced conventional munitions, laser and electro-optics systems, conflict simulation models, and consequence analyses to the development of precision weapons systems that will allow the U.S. military to destroy adversary targets while minimizing collateral casualties.

• **Effective Protection of U.S. Forces.** The Laboratory pursues technologies pertinent to theater ballistic missile defense and the detection of chemical and biological agents to protect U.S. forces against chemical and biological weapons. For example, Livermore researchers are investigating for DoD sponsors a variety of concepts for more advanced theater missile defense and for national defense against ICBMs. In addition, we analyze the capability of various interceptor systems to defend against and negate the effects of ballistic-missile-delivered WMD. Our work on ballistic missile defense lethality and DoD-sponsored work on detection and early warning of a biological weapon attack (JBREWS) are discussed in Section 2.2.2.

• **Efficient Operations.** Livermore's conflict simulation capabilities are being applied to military logistics issues for efficiently supplying equipment, which can make a decisive difference early in an operation and dramatically reduce overall costs. For example, our Joint Conflict and Tactical Simulation (JCATS) allows training, planning, and analysis from the campaign level to individuals operating inside a multistory building and is being used by more than 50 organizations (see Section 2.2.2).

2.3.2 Critical Infrastructure Protection

Situation and Issues

Presidential Decision Directive 63, issued in May 1998, addresses the need to better protect the nation against attacks on its critical infrastructures. Livermore is contributing through developing technologies for critical infrastructure protection and through sharing insights into the overall problem.

Livermore's Center for Global Security Research (CGSR, discussed in Section 2.2.5) conducted three joint seminars with Stanford University's Center for International Security and Cooperation on the vulnerability of the nation's critical infrastructures. The first two seminars helped the President's Commission on Critical Infrastructure Protection gather and digest information, leading to the Commission's final report. The third seminar, which focused on assuring critical national infrastructures, brought U.S. Attorney General Janet Reno to Lawrence Livermore, where she announced the initiation of the National Infrastructure Protection Center to detect, protect, and respond to cyber attacks on the U.S. critical infrastructures. Reno noted that success in this arena depends on the formation of effective partnerships between law enforcement, private industry, and the technical community, including the DOE laboratories.

Program Thrusts

Cyber Defense. Cyber defense is a critical component of infrastructure protection for the nation, the DOE, and the Laboratory. The Computer Incident Advisory Capability (CIAC) was established by DOE at Livermore in 1989 to help maintain the integrity of the Department's computer systems. CIAC provides on-call technical assistance to DOE and other government sites faced with computer security incidents. CIAC also develops cyber defense and network intrusion detection tools and provides public information about network security threats through a Web site (http://ciac.llnl.gov/). Through close ties with commercial vendors, law enforcement agencies, other government agencies, CIAC tracks the latest technology trends, product introductions, and system and network security threats and vulnerabilities. CIAC then disseminates information and advice to "client" organizations. In the event of an incident, CIAC assesses the nature of the attack and the extent of damage, produces or coordinates solutions (patches), provides advice on damage control and recovery, and assists law enforcement.

Livermore recently initiated a project in information operations to create a capability for understanding and assessing the national security implications of global interconnectivity and the nation's increasing reliance on networked critical infrastructures. A suite of software tools is being developed to permit the assessment of a wide variety of systems—computing, communications, command and control, energy and power generation and distribution, transportation, chemical production, manufacturing, and economic and financial. Through this project, we are developing the computer and information science foundation, the data representation models, the software components, and the automated analysis methods necessary to make information operations a viable and effective component of the nation's overall defense strategy. Rapid prototyping is being used so that potential sponsors can provide timely input on real needs and problems as well as access to real or simulated data so that the software tools will operate effectively on actual systems.

In spring 1999, the CIAC (Computation Directorate), the Computer Security Technology Center (Engineering Directorate), and the new project in information operations (NAI Directorate) were combined to form the Center for Information Operations and Assurance. This new center—with its capabilities in computer security incident response, computer security technology, and computer network analysis and assessment—will have an important role to play in partnership with the Justice Department's National Infrastructure Protection Center.

Laboratory Initiative

- Critical Infrastructure Protection (NN)

2.3.3 Support to Law Enforcement

Situation and Issues

The DOE laboratories are working with the Departments of Justice, Commerce, and Treasury to provide law-enforcement agencies with cutting-edge, crime-fighting technologies under a newly established "Partnership for a Safer America." In May 1998, the DOE signed memoranda of understanding with the FBI, the U.S. Customs Service, and the Bureau of Alcohol, Tobacco, and Firearms to establish formal working relationships that facilitate the transfer of DOE technology and technical expertise to law enforcement.

Program Thrusts

Law enforcement can benefit from Livermore technologies that were developed initially for on-site inspection of arms control treaties, detection of WMD proliferation activities, and response to WMD incidents. An example is our portable gas chromatograph–mass spectrometer (GC–MS), a system for quickly analyzing samples at the scene of a crime or accident. Potential law-enforcement uses for this instrument (which can identify chemicals to parts-per-billion sensitivity) include on-the-scene analysis of clandestine drug labs or unknown chemical releases, spills, or accidents. Using the GC–MS system, law-enforcement agents will be able to identify the substance in question within about 15 minutes, greatly facilitating on-scene investigation and evidence collection. A 55-pound portable GC–MS was delivered to the FBI in May 1999 (see Section 2.2.3).

Other technologies with potential application to law enforcement include thin-layer chromatography (TLC) and solid-phase microextraction (SPME). Our portable thin-layer TLC system can simultaneously analyze 100 samples for high explosives and other chemicals, and a digital-camera image-capture system interprets the TLC results and provides first responders with a simple readout of the compounds detected. For SPME, we have combined optical fiber technology with ultratrace analysis to create a "chemical dipstick." This technology can be used to collect ultratrace samples indicative of the presence of illegal drugs or other chemicals of law-enforcement interest. SPME samples can be secured (preserving chain of custody) for later analysis or inserted directly into the portable GC–MS for immediate analysis.

Laboratory Initiative

- Counterterrorism (NN)

SECTION 3

Laboratory Science and Technology–Enduring National Needs

Predicting an earthquake's behavior and how an "Xtremely" large structure will respond to it requires many steps in computational geophysics and engineering. In collaboration with UC Berkeley, Livermore scientists and engineers have developed the "Xtremely" powerful E3D seismic code, which simulates seismic wave propagation through a complex 3D geologic model of the San Francisco Bay Area, and SUSPNDRS, which simulates long-span bridge dynamics by accommodating nonlinearities in bridge geometry and material properties.

THE Department of Energy has enduring missions that are vital to the national interest. As part of the Department's national security missions, priorities include enhancing the nation's energy security, developing and making available clean energy technologies, cleaning up former nuclear weapons sites, developing effective and timely approaches for nuclear-waste disposal, and leveraging science and technology to advance fundamental knowledge and economic competitiveness.

Lawrence Livermore pursues major energy and environmental programs in which we can make unique and valuable contributions. These activities build on and reinforce our key strengths. The nation benefits from the application of our special skills to a wide range of national problems and from the cross-fertilization of ideas. In turn, program diversity keeps the Laboratory vital and helps to sustain the multidisciplinary base needed for national security work.

Major Research Areas

Three of the Laboratory's strategic councils set the strategic direction of Livermore's programmatic efforts to meet enduring national needs. The Council on Energy and Environmental Systems, the Council on Bioscience and Biotechnology, and the Council on Strategic Science and Technology are responsible for tactical planning and formulating a strategy for long-range program and resource development in their areas of interest. Livermore has programs and plans in four major research areas.

Energy. We pursue projects aimed at significant, large-scale innovations in environmentally sound energy production and usage. The availability of abundant, clean, and affordable energy provides the foundation for U.S. prosperity and economic growth.

Earth and Environmental Sciences. Our efforts are directed at demonstrating effective environmental remediation technologies, advancing the science base for environmental regulation, and accurately modeling regional weather and global climate conditions. We also develop technical tools for environmental management and mitigation.

Bioscience and Biotechnology. Bioscience research at the Laboratory advances human health by leveraging our physical science and engineering capabilities and focusing on genomics, disease susceptibility identification and prevention, and improved healthcare and medical biotechnology.

Fundamental Science and Applied Technology. We also pursue initiatives that bolster Livermore's research strengths, further develop the science and technology areas needed for the Laboratory's national security mission, and contribute to solving important national problems.

Partnerships and Collaborations

Much of our work to meet enduring national needs is executed in partnership with industry, academic institutions, and other laboratories. Partnering activities span a wide range—from very-large-scale strategic alliances to licensing of individual technologies, academic research, educational outreach, and support for the small business community.

Often partnerships and collaborations are the most cost-effective way for us to accomplish our programmatic goals. In addition, Livermore has a responsibility to move appropriate technologies developed in the course of our mission work into the marketplace, where the advances can have the maximum positive impact on the U.S. economy or other important national priorities.

Alignment with DOE's Strategic Plan

Livermore's strengths are well matched to the DOE's needs (and selected special needs of other customers), particularly in areas with high payoffs that entail significant scientific and technical risk. In addition to our national security efforts, we contribute to the strategic goals of other major DOE business lines described in DOE's Strategic Plan:

Energy Resources—Promoting secure, competitive, and environmentally responsible energy systems that serve the needs of the public.

Environmental Quality—Aggressively cleaning up the environmental legacy of nuclear weapons and civilian nuclear research and development programs, minimizing future waste generation, safely managing nuclear materials, and permanently disposing of the nation's radioactive wastes.

Science and Technology—Delivering the scientific understanding and technological innovation that are critical to the success of DOE's mission and the nation's science base.

3.1 Energy and Environmental Systems

The future security of the U.S. and the world depends on increased access to clean energy and on the preservation of a healthy environment. Many important advances are needed to ensure a prosperous, healthy, and secure future. Livermore's role is to apply its core capabilities to enduring national needs that require innovative science and technology.

Livermore is a leading science and technology laboratory in energy and environment. As a resource to government, in partnership with industry

Striving to Meet the Laboratory's Milestones by the Year 2001

Laboratory Activities	Milestones
Section 3 Laboratory Science and Technology—Enduring National Needs	• Livermore has expanded initiatives in nuclear materials stewardship, Visalia clean-up technology, and global climate modeling.
3.1 Energy and Environmental Systems	• The Joint Genome Institute has exceeded its sequencing goals, and the Laboratory has built support for follow-on efforts in functional genomics and structural biology.
3.2 Bioscience and Biotechnology	• The Laboratory's science and technology contributions are in functional genomics and structural biology. recognized by prizes, awards, and front-page publicity.
3.3 Fundamental Science and Applied Technology	• Livermore has become the leading DOE laboratory in industrial partnering, with extreme ultraviolet lithography among the largest DOE successes to date.
3.4 Partnerships and Collaborations	• The Laboratory is increasingly recognized as integral to the state of California through increased involvement with the University of California . . . and as a partner of the state's broad education initiatives.

and universities, we develop new energy and environmental capabilities for the nation. Our expertise and accomplishments in these areas enhance the Laboratory's primary mission in national security in two ways:

- By focusing our energy and environmental programs in research areas that have important national security aspects for nuclear materials management. These activities are natural extensions of—and are often tightly connected with—our national security mission. (See Figure 3-1.)
- By extending the scale, technical reach, demonstration orientation, and expertise that support Livermore's national security mission. These programs add to the intellectual vitality of the Laboratory and help to support the technology base needed to provide for national security.

The principal goals of our energy and environmental programs are to provide the scientific and technological basis for secure, sustainable, and clean energy resources for the U.S. and to reduce environmental risks to U.S. interests. Reaching these goals will require significant technological advances as well as broad cooperation among institutions. Our efforts focus on three critical areas in which the Laboratory can make a significant and positive difference. They are:

Nuclear Materials Management. Nuclear materials management is a fundamental, compelling, and enduring mission of DOE because the Department will be responsible for a vast array of nuclear materials for generations to come. Livermore is a key contributor to nuclear materials management through our stockpile stewardship and nonproliferation activities and through the support we provide to DOE's programs in nuclear energy, materials management, and proliferation-resistant nuclear fuel cycles. In partnership with other DOE laboratories, we work to develop an integrated approach to nuclear materials management to increase efficiency, reduce costs, and provide greater safety in all nuclear-materials-related activities.

Environmentally Sound Energy Technologies. The Earth's resources are finite, and expanding economies around the world are putting stress on traditional sources of energy and natural systems. Current technologies are not adequate to meet growing demands, and human activities (such as reliance on burning fossil fuels to meet energy needs) continue to increase the atmospheric concentration of CO_2 and other greenhouse gases. Livermore's focus is on important aspects of this carbon management issue. Significant, large-scale innovations are needed to provide clean, accessible, non-resource-depleting energy production. We will selectively pursue technologies for energy

Figure 3-1. General goals of Livermore thrust areas with dimensions in national security energy, and environment.

Thrust Areas: / Goals in:	Nuclear Materials Management	Environmentally Sound Energy Technologies	Environmental Management and Mitigation
National Security Reduce:	Nuclear dangers	Dependence on imported oil	Environmental disaster risks
Energy Wisely manage:	Nuclear materials	Generation and use of energy	Benefits and risks of energy options
Environment Clean up/reduce:	Nuclear legacy	Greenhouse gases	Toxic materials and carcinogens

generation and use in areas where the Laboratory has special expertise. We will also develop a better understanding of the environmental consequences of energy generation and use that drive technology selection and implementation.

Environmental Management and Mitigation. Dealing with the legacy of Cold War nuclear weapons production, DOE's major environmental responsibility, is a major task. At Livermore, we are also developing technologies to characterize and remediate contaminated groundwater faster and more cost efficiently than previously possible. Opportunities exist to accelerate cleanup at DOE contractor sites and to apply the technologies more broadly, including remediation of DoD property being released for public use and of Superfund sites throughout the U.S. In addition, the Laboratory has available extremely sensitive techniques for determining the mutagenic and carcinogenic potency of chemical pollutants. We will develop new technologies that reduce the time and cost to achieve specific risk reductions, complete the engineering demonstrations to bring these technologies to commercial use, and advance the scientific basis for risk assessment and regulatory reform. Moreover, Livermore has resources for responding to and providing assessments of a wide range of natural and man-made risks and disasters that pose threats to the environment and international security.

3.1.1 Nuclear Materials Management

Situation and Issues

Benefits of an Integrated Strategy. Regardless of the future of nuclear weapons or nuclear energy, DOE will be responsible, both internationally and domestically, for nuclear materials management (NMM) for generations to come. Because of the importance of proper management of nuclear materials to the strategic objectives of DOE, NMM in one form or another is a major ongoing responsibility of the Department.

By implementing an integrated strategy for NMM, the DOE will be recognized—at home and abroad—as the preeminent U.S. organization for nuclear materials science and technology.

DOE's responsibilities in NMM will be to ensure the safe, secure, and responsible use of nuclear materials throughout their life cycle. Specific objectives of this mission will be to:

- Establish a national nuclear policy framework for implementing the national security agenda through international cooperation.
- Build on recent steps—such as the Materials Protection, Control, and Accountability (MPC&A) concept—to ensure transparency, safety, security, and legitimate use of nuclear materials worldwide.
- Reestablish U.S. influence globally though cooperative cradle-to-grave nuclear energy research and development.
- Ensure the efficient management, use, storage, and disposal of nuclear materials.
- Be an enabler and patron of nuclear science to sustain a national resource of nuclear scientists, engineers, and facilities.

The direct benefits of integrated management of nuclear materials will be increased efficiency, reduced costs, and greater safety as the DOE carries out its stockpile stewardship and nonproliferation missions and meets its obligations in nuclear energy, material disposition, waste management, and environmental cleanup. The nation must guard against undue erosion of domestic capabilities to manage nuclear materials and deterioration of our ability to influence international nuclear developments. Rather, to the extent possible, NMM decisions should help to focus and provide an integrated set of capabilities so that the U.S. can proactively deal with important nuclear issues in the next century. Success in NMM will also help preserve the option for nuclear power in the U.S. and maintain U.S. leadership in the international nuclear materials arena.

Livermore's Capabilities and Contributions. Livermore is outstanding among U.S. national laboratories in both the scope and focus of its nuclear activities, from weapons materials research and management to nuclear fuel-cycle technology (including disposition of high-level wastes), nuclear systems safety, uranium atomic vapor laser isotope separation, and nuclear-related environmental and public-health assessments. This experience base gives Livermore the expertise and ability to provide key elements of a comprehensive U.S. stewardship program for nuclear materials.

Program Thrusts

A Roadmap for Nuclear Materials Management. We want to be recognized as a major national technical resource for ensuring safe, secure, economic, and environmentally sound conduct of nuclear operations. To this end, we will develop technical solutions for secure, safe, and coordinated management and control of nuclear materials. We have already begun to apply Laboratory expertise to major identified nuclear materials management issues. We will work with cognizant federal agencies to analyze key segments of U.S. nuclear materials regulations and definitions with respect to nuclear materials types, quantities, values, risks, and origins.

Yucca Mountain Project. Livermore is working to resolve issues regarding permanent disposal of high-level nuclear waste. For the Yucca Mountain project, we have played a major role in the design of the storage canister and engineered barrier, pioneering the approach of using waste-generated heat to keep the storage environment dry and leading in the development and evaluation of waste package materials and designs. The project is stepping up quality assurance (QA) efforts, including checking, certifying, and qualifying all project documentation as the project enters the potential licensing phase. We have been asked to take formal leadership roles in three major process model areas (engineered barrier system, near-field environment, and waste package) leading up to license application preparation. Livermore is also making substantial contributions in the waste form program area.

Licensing of the Yucca Mountain facility will likely require more scientific tools in modeling and performance confirmation. We are developing an integrated repository systems model that includes water infiltration, thermal effects, and reactive flow of radionuclides. We are also initiating development of an even more complete materials system modeling capability that will include the engineered system of man-made materials as well as the perturbed natural geologic system. This work, which takes advantage of dramatic increases in computational capability at Livermore, will help to optimize and evaluate the technical performance of the repository.

Transparency Measures for HEU Purchase. In 1993, the U.S. signed an agreement with the Russian Federation to purchase highly enriched uranium (HEU) that has been extracted from Russian nuclear weapons. Under this agreement, the HEU is blended down in Russia to low enriched uranium (LEU) and then shipped to the U.S., where the LEU is used in making fuel for nuclear power reactors. Livermore provides overall technical support for the transparency measures that serve as a technical basis for assuring each government that the other is abiding by the agreement. These measures involve on-site monitoring, document review, and nondestructive assays. (Also see other Livermore activities in Section 2.2.1, beginning on page 31.)

Nuclear Safety and Security Systems. As part of its nonproliferation mission, Livermore contributes to DOE's Material Protection, Control, and Accounting (MPC&A) program to improve the security of weapons-usable nuclear materials in the former Soviet Union (see Section 2.2.1). For example, we participate in DOE's Second Line of Defense Program, through which we are helping the Russian Customs Service install detection equipment to intercept illicit traffic in nuclear materials at Russian border crossings and checkpoints. We have also developed technologies to improve the physical security and protect sites in the U.S. with nuclear material or other top-priority assets. A sophisticated, computerized security system called Argus was designed, engineered, and installed at Livermore. It is continually being upgraded and enhanced. Argus is being installed at other DOE and DoD facilities.

In the area of nuclear safety, Livermore's Fission Energy and Systems Safety Program works with the NRC to develop software and computer-system design guidance that the Nuclear Regulatory Commission (NRC) uses to evaluate the design of safety-critical systems for U.S. plant retrofits. Overseas, where new nuclear power plants are being built, regulators and designers are using this state-of-the-art guidance to help ensure plant safety. In addition, Laboratory experts work with DOE and the NRC to perform analyses of the transportation of spent nuclear fuel using sophisticated risk assessment models. We also review safety analysis reports for packaging with regard to federal regulations and develop evaluation criteria for the NRC and DOE.

Laboratory Initiatives

- Nuclear materials management

3.1.2 Environmentally Sound Energy Technologies

Situation and Issues

Energy Production from Fusion. Livermore will conduct inertial fusion experiments with the National Ignition Facility and pursue advanced magnetic confinement fusion schemes to identify and make progress along the most promising path to full-scale deployment of fusion power. To establish the scientific basis of energy production from nuclear fusion is a long-standing goal at Livermore. The synergy of our fusion research and defense programs affords advantages in fusion research not found at other institutions.

Through inertial fusion experiments using high-power lasers and code development, and experience gained from underground thermonuclear testing, we are the leader in the worldwide effort to demonstrate the scientific feasibility of inertial fusion. These activities have established a solid basis for predicting the performance of the National Ignition Facility (NIF), a cornerstone of the Stockpile Stewardship Program that is under construction at Livermore. NIF is the critical facility for continued worldwide development of inertial fusion technology.

In the area of magnetic fusion research, the tokamak concept has been used to advance the science of high-temperature plasmas. Now attention is being focused on advanced and alternative plasma confinement concepts, such as the spheromak. The spheromak has an internal dynamo to create its confining magnetic field and is therefore a much simpler and more flexible engineering concept than a tokamak. Livermore completed construction and is testing a spheromak.

In both our magnetic and inertial fusion efforts, numerical simulation is crucial to success. Access to the new ASCI computer will increase our computational capability by more than three orders of magnitude in the next few years. An increase in DOE funding allocated to Livermore for magnetic fusion computing will allow us to take much greater advantage of the ASCI capabilities.

Nearer-Term Energy Alternatives. Because fusion is a clean energy option that will not be available for decades, security considerations warrant a renewed examination of fission energy alternatives and new exploration, production, and utilization methods for hydrocarbon fuels and other alternatives. The Laboratory's strengths in earth and environmental sciences, materials science, engineering, and computational modeling will be applied to develop more efficient coal, energy storage, renewables, and emission separation and sequestration technologies.

Transportation Systems. Transportation systems are a leading contributor to greenhouse gases and increasingly will become targeted for CO_2 emission reductions. About 30% of the global CO_2 emissions from fossil-fuel stems from the use of oil for transportation. Livermore's expertise and programs in advanced materials, systems modeling, alternative fuels (e.g., hydrogen), and energy conversion and storage (e.g., fuel cells for stationary and eventually mobile applications) provide the basis for expanded work in this area.

Grand Challenge of Climate Modeling. A grand challenge that faces the international scientific community is determining the record of Earth's climate over recent centuries and assessing whether humans significantly impact the global and regional climate. As a major contributor to the international global climate modeling effort, Livermore supports DOE's mission to understand the environmental consequences of fossil-fuel use by capitalizing on the Laboratory's strengths in modeling and atmospheric sciences and the computing capabilities available through DOE's Accelerated Scientific Computing Initiative (ASCI).

DOE and several of its laboratories are planning the Accelerated Climate Prediction Initiative (ACPI) within a DOE Strategic Simulation Initiative. Livermore is a principal participant in this planning process. We expect to play a key role in developing both simulation models and the infrastructure needed to support these activities (e.g., code and data standards, databases and archives, and the computer network). Livermore also has major responsibilities in the Program for Climate Model Diagnosis and Intercomparison, and we are responsible for the development of atmospheric physical and chemical models directed at specific critical issues such as ozone, CO_2, and aerosols.

Program Thrusts

Inertial Confinement Fusion (ICF). Livermore is working to establish the scientific basis for demonstrating fusion power. To this end, our goal is to demonstrate for the first time in a laboratory fusion ignition and energy gain using inertial fusion in the National Ignition Facility (NIF), which is now under construction at Livermore, Demonstration of fusion ignition and energy will be conducted in parallel with a research program on fusion driver concepts (ion-beam accelerators and lasers) to meet the efficiency and repetition-rate requirements of inertial fusion power plants. In particular, for DOE's Office of Science, we are working closely with Lawrence Berkeley National Laboratory to assess and advance the technology for heavy-ion accelerators as ICF drivers for commercial fusion power generation. We are also working with the University of Rochester Laboratory for Laser Energetics on advanced technologies for laser drivers.

Spheromak Experiments. Livermore is beginning to conduct tests using a 1-meter-diameter spheromak. The Sustained Spheromak Physics Experiment (SSPX) facility was dedicated in January 1999. The SSPX aims to demonstrate modest heat containment in the presence of dynamo action, achieve a significant plasma temperature in the few-hundred-electronvolt range, and examine issues of magneto-hydrodynamic stability. Beyond these experiments, a new facility will be required.

Tokamak Experiments and Magnetic Fusion Simulation. Livermore collaborates in experimental studies centered on advanced performance and power handling for the tokamak using the DIII-D tokamak at General Atomics. In the DIII-D program, we have the lead role in the critical area of power handling (and diverter physics in general), and we contribute importantly to the study of advanced operating scenarios. In addition, we provide leadership in the use of large-scale simulation of plasmas as a very cost-effective way of carrying out fusion research. We have developed the CORSICA code, which couples various computational models (such as power input, heat loss, and magneto-hydrodynamic equilibrium and stability) that proceed on very different timescales. We are building on the capabilities of CORSICA to take advantage of greatly expanded computational power becoming available through ASCI. As our resources permit, we will move toward ASCI-compatible, integrable code structures for magnetic fusion. In-house ASCI computing capabilities will be used to model fusion physics phenomena and to design and analyze integrated fusion reactions and systems.

Innovative Research to Meet Energy Needs. We will explore technologies that can lead to significant, large-scale innovations in energy production or that can help manage carbon emissions. The Laboratory's strengths in materials, instrumentation, and computational modeling will be applied to develop carbon sequestration technologies and more efficient methods of obtaining oil, gas, coal, and renewable energy. For example, we participate in DOE's Natural Gas and Oil Technology Partnership, an alliance that combines the resources and experience of the nation's petroleum industry with the capabilities and technologies of the national laboratories. This integration expedites development of advanced technologies for better diagnostics, more efficient drilling, and improved natural gas and oil recovery.

Alternative-Fuels Transportation. We will expand the existing technology base for integrated alternative-fuels production, fueling, and automotive drive systems. In particular, we will develop technologies for very efficient steam electrolysis, for auxiliary energy storage capabilities (flywheel and supercapacitors), and for practical, safe storage of hydrogen fuel onboard a vehicle. We will continue developing an economic analysis code for optimizing the deployment of hydrogen transportation systems, both during the early stages of transition and for their ultimate integration with renewable and nuclear carbonless energy sources.

Atmospheric–Ocean Modeling from Global to Local Scales. Our goal is to be a leader in DOE's Accelerated Climate Prediction Initiative for developing and integrating predictive atmosphere–ocean models on a global-to-local scale. Using coupled atmosphere–ocean simulation codes integrated with data from satellites and other sensor systems, we will achieve unprecedented prediction, speed, and accuracy in our climate, weather, and atmospheric dispersion modeling. We are working to develop more accurate climate and weather forecast modeling at the regional scale. It is through predictions and measurements on a regional scale that we can observe and better understand the potential impact of human activities on the global climate. Improving climate and weather models requires a much better understanding of the relationships among the atmosphere, ocean, and land systems. Use of these models will facilitate responsible environmental management, reliable climate predictions, and anticipation of and effective response to natural and terrorist environmental emergencies.

Ocean Carbon Sequestration. Carbon dioxide emissions from fossil-fuel use may adversely impact global climate. The oceans naturally absorb about one-third of the carbon dioxide from human-caused emissions, but climate change could be mitigated if a way could be found to accelerate the ocean's absorption of carbon in an environmentally acceptable way. To develop the scientific base needed to make technical and policy decisions, Lawrence Berkeley and Lawrence Livermore national laboratories have been called upon to form and codirect the DOE Center for Research on Ocean Carbon Sequestration (DOCS). Participating institutions also include Massachusetts Institute of Technology, Rutgers, Scripps, Moss Landing, and PICHTR. The center's goal is to better understand the efficacy and environmental impacts of various ocean sequestration options, including direct injection of carbon dioxide into the deep ocean and fertilization of marine biota. Livermore's role in the center includes leading efforts to numerically simulate ocean carbon sequestration.

Tera-Scale Model Development. In preparation for an expanded effort in climate and weather prediction modeling, we are focusing on parallelization of our codes to increase their speed and resolution, and we are incorporating better physics simulation models and physics data to improve accuracy. Improved weather prediction capabilities are important for our regional climate modeling and for our atmospheric release advisory capabilities (see Section 3.1.4). We have collaborated with the Naval Research Laboratory at Monterey, California, to adapt their regional weather model for use on highly parallel computers and couple it to our global- and local-scale models. This capability enables us to predict rainfall patterns in California, such as during the recent El Niño season, with encouraging accuracy.

Laboratory Initiatives

- Spheromak Fusion Reactor (AT).
- Accelerated Climate Prediction Initiative (KP).
- Fuels Assessment (EE)
- Hydrogen as an Alternative Fuel (AR)

3.1.3 Environmental Management and Mitigation

Situation and Issues

Remediation Technologies and Risk Assessment. By using Livermore's recent innovations in remediation technology and tools to assess the health risk from low-level exposure to toxic materials, the national mortgage of environmental cleanup can be significantly reduced. In a demonstration of an innovative remediation technology in Visalia, California, the rate of soil and groundwater cleanup of an old utility pole yard was increased by nearly 5,000 times, achieving in six weeks what would have taken 600 years with conventional techniques already in use at that site. The work was executed by Southern California Edison, with consulting assistance from Livermore and the University of California. The technology used at Visalia—a combination of dynamic stripping and hydrous pyrolysis/oxidation—is in the process of commercialization. We would like to assist with its application at Savannah River, Portsmouth, Hanford, and DoD sites, such as Mare Island.

Moreover, Livermore offers a portfolio of assessment, control, and remediation technologies demonstrated through work with industrial partners. For example, we have shown that we can control and pull back a distal underground plume of contaminants by pump-and-treat techniques. In addition, we are using accelerator mass spectrometry to assess the effects on human health of carcinogens at realistic environmental exposure levels. This science and technology can greatly improve the effectiveness of remediation strategies in reducing health hazards.

Emergency Response Capabilities. Livermore has assessment and effective response capabilities needed to deal with a wide range of natural and man-made risks and disasters that pose threats to the environment and international security. With atmospheric modeling capabilities, ASCI-scale computers, and national security access and responsibility, Livermore is poised to develop the nation's premier capability for atmospheric dispersion prediction and emergency response on all critical time scales and space scales globally.

The National Atmospheric Release Advisory Center is located at Livermore, and we are responsible for the Atmospheric Release Advisory Capability (ARAC). ARAC is a formally recognized national emergency response service for real-time assessment of atmospheric releases involving nuclear, chemical, biological, and natural hazardous material. ARAC's primary function is to support the DOE and DoD in the event of radiological releases. Under the Federal Radiological Emergency Response Plan, ARAC also assists other federal agencies and, with approval of DOE, it supports local, state, and international agency responses to natural and anthropogenic releases. Since 1979, ARAC has supported more than 900 exercises and over 150 alerts, accidents, and disasters involving radiological and chemical releases.

Program Thrusts

Faster Remediation Technologies. To reduce environmental cleanup costs within DOE and nationwide, we will develop and implement accelerated remediation technologies, which will not only reduce the cost of cleaning up subsurface contamination but will also allow land to return to productive economic uses more quickly than previous methods. Our strategy is to target DOE, DoD, and civilian contamination problems as opportunities for technology development and application. To validate the performance and the economics of our technologies for other federal and commercial cleanup sites, we will continue building working relationships with industry and regulators on small and large scales and develop the engineering and economic bases for advanced remediation technologies.

We plan to apply our accelerated remediation technologies at the Portsmouth Gaseous Diffusion Plant and the Savannah River Plant within the DOE complex and at the Wyckoff Superfund site in Seattle, Washington. Collaborating with the Navy, we plan to demonstrate the technology at the Port Huenueme engineering facility later this year. So far, three commercial entities have licensed these technologies and are pursuing their application at sites that include privately owned facilities.

Basic Research on Environmental Cleanup. To reduce the cost of environmental cleanup and make it faster over the long term, DOE is sponsoring projects in basic science related to environmental management through its Environmental Management Science Program. In six grants from the program, our work ranges from molecular geochemistry to a large-scale look at contaminant movement at the Livermore site. Through several projects, we are studying the movement of contaminants in the vadose zone, a region between the surface and the water table that protects the water from surface contaminants. Livermore researchers are also developing improved computer algorithms and measurement capabilities for subsurface imaging that can be applied to improve environmental management. In addition, we are examining emission-free, high-temperature means for treating and disposing wastes that contain actinide elements (including nuclear materials).

Radionuclide Release Response. The Atmospheric Release Advisory Capability (ARAC) was founded at the Laboratory by the DOE to predict the dispersion of radioactivity into the atmosphere during nuclear accidents, threats, attacks, and terrorist incidents and thereby help stem dangers. ARAC now provides emergency response capabilities to DOE, DoD, and other customers to deal with the release of other types of hazardous and toxic materials. The models used for ARAC continue to be upgraded.

Improvements to ARAC. In our ARAC modernization effort, we are providing capabilities to help facilitate services to current and potential new customers. For example, we are developing Web-based network communications to the ARAC central system. During an actual event, this capability will allow simultaneous access by multiple emergency response agencies to ARAC's incident characterization and assessment products.

In addition, national security concerns have expanded beyond the nuclear threat to include chemical and biological releases. Potential ARAC applications range from responding to accidents to countering terrorism threats. We are coordinating ARAC research efforts with DOE's Chemical and Biological Nonproliferation Program and developing the capability to predict the fate of chemical or biological releases both outdoors and indoors (for example, in buildings and subways). Our focus is on the prediction of airflow and dispersion in difficult-to-model urban environments. In particular, we are developing an ARAC interface to Livermore's very-high-performance computers to provide real-time local meteorological and dispersion forecasts, detailed vulnerability and mitigation assessments, and accurate predictions of the dispersion and fate of chemical or biological agents released into a complex urban environment. Our goal is the capability for planning, training, and, ultimately, emergency-response assessments of urban chemical and biological releases.

Expanded Environmental Security Capabilities. We are working to establish a long-term relationship with DOE and DoD to provide on-demand operational capability and analysis of continuing national and international issues pertaining to the environment, particularly scenarios that would adversely affect regional stability. This effort will require integrating a wide variety of models (from enhanced physics to ecosystem response), transforming the codes to the ASCI environment, and managing vast volumes of data while providing timely, customer-focused results. We will provide dependable service for emergency, military, and political management of emerging regional and global environmental situations and their relationship to regional security. Working with the DOE and other government agencies, we will promote confidence-building cooperative steps to mitigate environmental stresses on regional security in areas of importance to U.S. strategic interests.

Risk Assessment Consortium. Together with industry, university, and regulatory partners, we will form and direct a consortium to apply the extreme sensitivity of accelerator mass spectrometry to understanding mutagenic and carcinogenic mechanisms of chemical pollutants. Our goal is to determine the actual genetic effects—ones that damage and repair—from exposure to environmentally relevant levels of toxic materials, thereby aiding the transition to science-based risk analysis. Problem owners and regulating agencies will then have the basis for planning the most effective risk reduction and remediation expenditures. Inclusion of regulatory agencies in the consortium is essential to ensure support, confidence, and use of the results of the work.

Laboratory Initiative

• Environmental Security

3.2 Bioscience and Biotechnology

Working with academia, government, and industry, we leverage the Laboratory's capabilities in the physical and engineering sciences to conduct bioscience and biotechnology research of national importance. Livermore is part of an accelerating revolution in biology and biotechnology. The groundwork for this revolution was laid in the 1980s with a shift of the national research strategy toward large-scale, complex projects, notably the Human Genome Project. This project, in which Livermore is a significant participant, is creating material resources, technologies, and information to set the stage for dramatic advances in the next century.

Livermore's bioscience program grew out of a long-standing biomedical research mission to identify and characterize the effects of ionizing radiation on human health, which led to the development of sensitive instrumentation for genomics research. Today and in the future, research activities in biology, biotechnology, and healthcare fit well in a technology-rich, multidisciplinary, broad-based national laboratory. The core program in biosciences is multidisciplinary, drawing upon Livermore's matrix organization in physical sciences and engineering. Many of bioscience program staff are physicists, chemists, engineers, mathematicians, and computer scientists who are brought in from the diverse laboratory infrastructure and who work side-by-side with the core biologists and biochemists.

A hybrid vigor results from the cross-fertilization of talents and, moreover, provides our bioscientists access to the latest technologies in physical sciences and engineering inherent in the parent discipline organizations. Conversely, bioscientists at Livermore make significant contributions to national security activities and other major programs at the Laboratory. For example, we are developing detection technologies to monitor and characterize biological weapon proliferation activities and to respond in the event of an emergency. This very important "spinback" to the Laboratory's defining mission increases the benefits to the nation of sustaining a strong bioscience and biotechnology program at Livermore.

Grand challenges in the Biosciences. We identify four challenges that align with DOE's and the Laboratory's missions and draw upon our existing personnel talents and core competencies.

- **Genomics:** Learning how living systems function and using that information to enhance our nation's security, preserve the environment, and ensure a better quality of life.
- **Biological Nonproliferation:** Providing new, more sensitive tools for the rapid identification, isolation, and characterization of potential pathogens.
- **Disease Susceptibility—Identification and Prevention:** Determining what causes disease, why some people are more susceptible than others, and what we can learn to prevent it.
- **Health Care and Medical Biotechnology:** Developing tools for cost-effective, high-quality health care for our nation.

Bioscience and biotechnology research at Livermore is supported by diverse sources. For many years, most of the funding for Livermore's bioscience program came from the DOE Office of Health and Environmental Research (OHER). More recently, OHER support has hovered around 50% of the overall budget. That office supports major research efforts at Livermore, including the Joint Genome Institute activities. Our focus remains on serving the needs of DOE OHER and developing with them new program opportunities. Additional support comes from other sources such as the National Institutes of Health (NIH), other government sources, and industry. The NIH is the major funding source for biosciences research in the U.S., and funding from this agency is expected to continue growing. NIH and peer-reviewed funding is essential for LLNL bioscientists to maintain credibility with their peers. Moreover, with funding from multiple sources, the Laboratory enriches the biosciences research program for DOE, and we are able to apply the Laboratory's special science and engineering skills to meet the important needs of a variety of sponsors.

3.2.1 Genomics

Situation and Issues

Genomics Research. Genomics is a multidisciplinary science whose goals are to characterize the genetic material of mammalian, plant, and microbial species. Research efforts include studies of genome organization (examination of the interposition of genes with structural and regulatory elements in DNA), identification of genes, and prediction of the proteins that genes produce. Comparative genomics (cross-species analysis) is an important method to study evolution, gene function, and human disease.

The enabling technologies for genomics research include physical mapping, DNA sequencing, gene discovery, computations and informatics, and automation and robotics. The development of DNA sequence identification as a unique identifier of species or individuality is relevant to this effort. In particular, Livermore's Human Genome Center has been at the forefront of DOE's efforts to advance the needed technologies and perform accurate, high-throughput DNA mapping and sequencing of the human genome. The center recently merged with the two other DOE genome centers at Berkeley and Los Alamos national laboratories to create the DOE Joint Genome Institute (JGI). The institute's primary task is to map and sequence by 2003 a substantial fraction of the 3 billion total bases of the human genome. In addition, the genome of several microbes of interest to the DOE will be sequenced, with the initial effort at Livermore.

In addition to our work with the JGI, we are working with universities and other research institutions to provide a comprehensive public collection of complementary DNA (cDNA) clones. The DOE-sponsored I.M.A.G.E. Consortium, based at Livermore, includes over 1.9 million arrayed clones, 1.5 million sequences, and over 30,000 mapped cDNAs.

Program Thrust

Joint Genome Institute. We are providing the technical and managerial support required for the JGI to succeed in its ambitious goals. In partnership with Lawrence Berkeley and Los Alamos national laboratories, we have implemented a strategy for "production mode" DNA sequencing. Central to this production mode is the operation of a new DNA sequencing facility in Walnut Creek, California. Continued success in production sequencing also depends on an effective program of new technology development, which will make efficient use of the laboratories' capabilities as well as external sources. In particular, Livermore's expertise in engineering and the physical sciences will be applied to develop new instrumentation, automation, and integrated robotics systems to minimize human intervention, reduce error, and reduce costs.

The JGI provides immediate and full public data release and relies on Livermore's unique computing and bioinformatics expertise to provide for analysis, storage, and networking of data.

Laboratory Initiative

• Joint Genome Institute (KP)

3.2.2 Biological Nonproliferation

Situation and Issues

With the foundation laid by the Human Genome Project, we are able to quickly respond to the national call for basic and applied research in the area of chemical and biological nonproliferation. Since 1991, we have been researching certain elements of molecular biology with the goal of developing, analyzing, and synthesizing molecular information regarding potential biowarfare agents. Researchers at Livermore have actively focused on the foundational biology needed for this important program.

Program Thrusts

Microbial Studies. We couple our technologies and competencies in the national security area (e.g., biological nonproliferation and counterterrorism) with those in the biological sciences (e.g., microbial genetics, enzymology, and genomics) and in engineering (e.g., microfabricated bioinstruments). Applications relevant to national security include the detection and biological signature analysis of samples collected from air, soil, or water. Specific applications of genomic technologies support our national security, energy, and environmental programs. Of interest are methods and resources to identify species within the animal, plant, and microbial communities for use in forensic, bioremediation, or biodiversity applications. Such methods might be DNA- or antibody-based, but new technologies are also sought. Important to these methods are automated approaches for scale-up, miniaturization, and multiplex analysis.

Technology Development. Livermore researchers have recently joined with colleagues at Los Alamos, Brookhaven, and Sandia national laboratories to develop a five-year research plan that will expand the three laboratories' research in the areas of DNA-based "fingerprint" signatures, structure-based attribution, and molecular epidemiology. Several underlying technology development efforts will support these three general areas. These include (1) rapid identification, isolation, and characterization of unique DNA, (2) characterization of microbial backgrounds, (3) characterization of signatures of genetic engineering and virulence factors, and (4) baseline genomic sequencing of selected pathogens. Each program element is designed to the specific support program objectives of providing warning of any biological warfare attack, characterizing the nature and extent of such an attack, and providing forensic evidence to aid in identifying and prosecuting perpetrators. These same tools will have strong spin-off benefits for the development of vaccines, drugs, and other medical treatments, as well as for environmental bioremediation.

Laboratory Initiatives

• Microbial Genomics (KP)
• Chemical and Biological Nonproliferation Program (NN)

3.2.3 Disease Susceptibility Identification and Prevention

Situation and Issues

Disease and Genes. The focus of research in disease susceptibility and prevention is the relation between an individual's genes and disease. Cancer and other human diseases are often caused by defective proteins or damage produced by radiation or by molecules that bind to and alter DNA. To understand the structure of proteins and defects in the structure, we must rely on high-resolution experimental methods and computational modeling of the molecules.

Research at Livermore already has led to identifying the genetic causes of a number of diseases, such as two forms of dwarfism. Other efforts have led to a clearer understanding of the role of cooked food (food mutagens) in genetic changes and cancer. In these activities, we are drawing upon existing capabilities at the Laboratory, including cloning, gene expression, biophysics and structural biology (crystallography, x-ray diffraction, and nuclear magnetic resonance), analytical chemistry (biological accelerator mass spectroscopy), computational biology, and bioengineering.

Program Thrusts

Gene Identification. Our goals are to identify genes that control individual susceptibility (with emphasis on DNA repair genes), understand how the associated proteins might be involved in the disease process, assess human variability for these genes, and estimate risk for disease based upon an individual's genetic constitution. We will couple this research to genomic approaches, which should expedite rapid discovery. A special focus area will continue to be risk assessment of ill health from adverse exposure to radiation and chemicals, either directly through human studies or based on cellular and animal data.

Livermore maintains state-of-the-art x-ray crystallography and nuclear magnetic resonance facilities, for both our own research and external collaborations, as well as a protein structure prediction center for the scientific community. We will develop new molecular, instrumentation, and computational methods that will allow the genome of any organism to be scanned and analyzed quickly for gene content and function. By coupling biophysical measurements of protein structure with computational approaches for protein folding and function prediction, we may be able to link gene and protein information to measure genetic variation and biochemical function in humans. These efforts will take advantage of the unique high-speed computing capabilities at Livermore.

Laboratory Initiatives

• Disease Susceptibility: Genetic and Structural Basis (KP)
• Computational Biochemistry (KP)

3.2.4 Health Care and Medical Biotechnology

Situation and Issues

Cost-effective Technologies. Affordable, accessible health care has become an issue of national importance. Each year in the U.S., about 14% of the gross domestic product is spent on health care—about $3,000 for every American. Livermore researchers are working to develop more cost-effective healthcare technologies. Projects exploring improved or new healthcare technologies evolve at Livermore from diverse research efforts, in many cases applying or adapting technologies, devices, and processes that were developed for our national security mission. Livermore efforts are already having an impact on the frontiers of research and in the treatment of such maladies as cancer, heart disease, stroke, diabetes, osteoporosis, and repetitive strain injury as well as such specialty fields as ophthalmology and prosthesis design and manufacture. The ultimate goal of such work is to transfer new, cost-effective devices to industry for manufacture.

Our efforts are usually multidisciplinary and often involve external collaborators. We work closely with healthcare deliverers and industry to develop and demonstrate novel healthcare technologies, such as high-tech tools to aid stroke treatment. Increasingly, industry is expressing interest in partnering with and funding development activities. We benefit from our proximity to the San Francisco Bay Area's biotechnology firms, many of which lead the country in research.

Program Thrusts

Device and Method Developments. Current major application areas include medical device development for diagnosis and treatment of stroke, radiation treatment planning, and patient monitoring. Projects combine the Laboratory's expertise in sensors, imaging, computational physics, informatics, microfabrication, and lasers with university and industry knowledge in biomedicine. For example, Livermore is developing novel methods and surgical tools for the treatment of stroke. We have adapted physics simulation capabilities into a unique planning tool (PEREGRINE) for radiation treatment of cancer, which could help the more than 350,000 Americans diagnosed each year with a curable form of cancer. We will also explore the establishment of a molecular medicine program to couple our strengths in molecular and cellular biology to the development of diagnostic instruments and, ultimately, to clinical treatment.

Laboratory Initiative

• Pilot Projects in Biomedical Engineering (KP)

3.3 Fundamental Science and Applied Technology

One of DOE's primary missions is to provide capabilities that enable the U.S. to maintain its world leadership in science and technology. It is widely recognized that the nation's advances of fundamental knowledge and innovation provide the U.S. an advantage in an increasingly competitive world.

The pursuit of fundamental science and the advance of applied technology go hand in hand at Livermore. State-of-the-art applied technology is used to advance fundamental science in areas pertinent to the Laboratory's major missions. In some cases, the work is sponsored by DOE's Office of Science or other customers that take advantage of the unique research capabilities and facilities present at the Laboratory. In other cases, the work is supported by Laboratory Directed Research and Development funding and extends Livermore's capabilities in anticipation of new mission requirements.

The Laboratory's scientific advances—and technologies developed in pursuit of fundamental science—have important spinoff and spinback applications. For example:

• We have successfully demonstrated that adaptive optics using a laser guide star can correct for atmospheric turbulence. Livermore's development and installation of a laser guide star on the 10-meter-diameter Keck II Telescope on Mauna Kea, Hawaii, will improve significantly the quality of its images. The laser guide star technology is helping us in the design of the National Ignition Facility.

• The discovery of fluid metallic hydrogen—a new state of matter—contributes to planetary science and generates new knowledge about the properties of hydrogen that is needed for Laboratory programs.

• Livermore's petawatt laser has enabled physics experiments never before possible and also has precision cutting applications for advanced manufacturing in stockpile management and broader applications. In addition, technologies developed to build the petawatt laser are enabling revolutionary advances in flat-panel displays for computers and televisions.

• Materials synthesis and materials engineering at the atomic level have led to the development of an aerogel dielectric that will contribute to continuing advances in integrated circuit performance. These developments have also led to multilayer optics (grown layer by layer) that enable mapping the x-ray spectrum of the sun in incredible detail and provide extraordinary images of its surface.

• With the U.S. Geological Survey, Livermore has made recent progress on methane clathrate EOS stability at various temperatures and pressures to understand the implications for future exploitation as an energy source and its relation to a clathrate from carbon dioxide. Like methane, carbon dioxide also forms clathrates in the deep sea. If carbon dioxide could be relatively stable as a clathrate in the deep sea or in deep-sea sediments, this could be a promising option for deep-sea carbon sequestration.

Alignment with the DOE Strategic Plan

Our fundamental science and applied technology efforts align with the DOE Strategic Plan. The Department's strategic objectives in science and technology are:

• To develop the science that underlies DOE's long-term mission.
• To deliver leading-edge technologies that are critical to the DOE mission and the nation.
• To improve the management of DOE's research enterprise to enhance the delivery of leading-edge science and technology at reduced costs.
• To assist in the government-wide effort to advance the nation's science education and literacy.

Mission Directed Science and Technology. We *develop the science that underlies DOE's long-term mission, and we deliver leading-edge technologies* to the nation by applying Livermore's special expertise and capabilities. As an institution with stable mission responsibilities and program continuity, the Laboratory has developed a strong science and technology infrastructure. We focus on our unique capabilities and research facilities on problem solving to meet the demands of our national security mission. This science and technology base also enables us to meet other important national needs and respond to new challenges.

Laboratory Directed Research and Development. To further *develop the science that that underlies DOE's long-term mission*, we sustain and strengthen the Laboratory's science and technology base through effectively managed internal investments in Laboratory Directed Research and Development (LDRD). LDRD supports research and development projects that enhance Livermore's core strengths, expand DOE's and the Laboratory's scientific and technical horizons, and create new capabilities in support of the Laboratory's missions. These investments help Livermore to meet challenging, long-term mission needs effectively and to respond promptly to national priorities as they change.

Partnerships That Create New Capabilities. We *deliver leading-edge technologies and contribute to DOE's management of its laboratories* as an integrated system through partnerships with industry and other laboratories (see Section 3.4).

Effective Academic Collaborations and Science Education Programs. The Laboratory also partners with universities and *advances the nation's science education and literacy* through academic collaborations and science education programs (see Section 3.4).

3.3.1 Application of Mission-Directed Science and Technology

Situation and Issues

To achieve mission goals, Livermore has special capabilities for meeting some of the nation's broader challenges in fundamental science and applied technology. These special research capabilities and facilities are a consequence of Livermore's overall size, the need for technologies and capabilities that do not exist elsewhere, and the fact that essential elements of our national security mission are classified. Much of the expertise necessary to support national security programs resides within the Laboratory. For example, we have capabilities to develop state-of-the-art instrumentation for detecting, measuring, and analyzing a wide range of physical events. We also have expertise to support innovative efforts in advanced materials, precision engineering, microfabrication, nondestructive evaluation, complex-system control and automation, and chemical, biological, and photon processes.

Program Thrusts

Applications of our special capabilities are meeting the nation's challenges in fundamental science and applied technology, including:

Astrophysics and Space Science. In partnership with many other scientific institutions, we make important advancements in astrophysics and space science through application of the Laboratory's special expertise in high-energy-density physics, nuclear fusion, and scientific computing. Livermore researchers participate in a wide range of observational, experimental, and theoretical activities—from the creation of supernova instabilities in the laboratory (using Livermore's Nova laser) to the sighting of the most distant radio galaxy and the discovery of a quasi-stellar object with one of the most luminous starbursts ever.

Livermore also makes important advances in instrumentation, as demonstrated by the development of sensors for the Clementine satellite, which mapped the entire surface of the Moon. This sensor technology has led to other advances, such as development of a revolutionary camera system and its use to discover massively compact halo objects (MACHOs). A Livermore-led international team has completed more than 1,600 nights at Australia's Mount Stromlo Observatory gathering and analyzing terabytes of data relating to MACHOs.

Accelerator Technology. We make strong contributions to national accelerator development programs, capitalizing on the way our physicists and engineers work together to solve problems in accelerator design, technology, and manufacturing. Livermore was part of the three-laboratory effort that designed and built the B-Factory at the Stanford Linear Accelerator Center (SLAC). Working with SLAC and Berkeley, we contributed across a broad range of disciplines, ranging from particle physics to precision machining. As part of an international collaboration that includes the same tri-laboratory team, Livermore is now pursuing research and development for the Next Linear Collider. Important national security applications of our accelerator expertise include the further development of an advanced hydrodynamic testing capability.

Microelectronics and Optoelectronics. The Laboratory's strengths in microelectronics and optoelectronics help us meet the demands for enhanced surveillance of aging nuclear weapons as well as for advanced diagnostics and precision target fabrication in the inertial confinement fusion program. Expertise in thin-film processing and microfabrication technology has many applications in lithography, semiconductor processing and process modeling, electronics packaging, communication and computing systems, and biotechnology. Advances have made possible microtools for health care, portable biological agent detectors, and diagnostics for the National Ignition Facility.

Advanced Materials and Materials Science. Our work in materials science ranges from fundamental research on the properties of materials to the engineering of novel materials at the atomic or near-atomic levels, which are often pursued to the stage where they can be readily manufactured. Aerogels and nano-engineered multilayer materials developed at Livermore have tremendous implications for new products and future Laboratory programs. Other advances include highly efficient energy-storage and energy-generating components, ultralight structural materials, specialty coatings, and novel electronic, magnetic, and optical materials.

The Laboratory's fundamental research includes work for the Office of Basic Energy Sciences in areas such as interfaces and grain boundaries and their role in the behavior of metals and the superplastic deformation of metals and intermetallics. Through efforts in fundamental science, we have also developed an improved understanding of material deformations and radiation effects on materials. In addition, we are making significant progress on an exciting LDRD-funded initiative to develop a basic yet detailed understanding of the mechanical properties of metals through the development of a multiscale model of metals that is validated by experiments. One goal is to understand dislocation dynamics at the microscale (micrometers), which critically affects the bulk mechanical properties of metals. Multiscale modeling uses the Laboratory's supercomputers and involves simulations at three length scales (atomistic, micro scale, and mesoscale) with information passing from the shorter to longer scales.

Laser Science and Technology. The Laboratory has unmatched capabilities in high-energy and high-power solid-state lasers. We will apply this expertise to meet critical needs in national security, energy security, and environmental applications. In addition, we will expand collaborations with industry and other partners to identify laser and electro-optics technologies that can be developed and transferred to the private sector.

Our expertise in lasers also has exciting scientific applications. An important breakthrough in physics of laser–matter interactions was reported by Livermore researchers in 1999—nuclear fusion driven by an ultrafast "tabletop" laser. The approach entails generating fusion reactions in small clusters of heavy hydrogen gas that are superheated suddenly by short, extraordinarily intense laser pulses. "Tabletop fusion" may offer a promising avenue for future production of compact, economical sources of neutrons. These sources could be useful for neutron radiography and in studying neutron damage to materials.

Agile Manufacturing Technology. Livermore is working on the U.S. Army's Totally Integrated Munitions Enterprise (TIME) program to improve munitions manufacturing. This work applies agile manufacturing technologies, developed earlier under DOE's Technologies Enabling Agile Manufacturing (TEAM) program, that includes our Open Modular Architectural Controller software. This "intelligent" controller works with "smart" sensors and actuators to enable production lines to shift rapidly (within days) from one product to another. The benefits include greater flexibility, increased efficiency, high product quality, faster turnaround time, and less waste than previous controller systems.

Major Initiatives

• Accelerator Technologies (Multiple Offices)
• Materials Studies and Surface Characterization (KC)
• Computational Materials Science and Chemistry (Multiple Offices)

3.3.2 Laboratory Directed Research and Development

Since its inception, Livermore's Laboratory Directed Research and Development (LDRD) Program has provided support for many important and innovative scientific and technological advances. The LDRD Program has played and continues to play a vital role in developing new science and technology capabilities that respond to the DOE's and Laboratory's missions and in attracting the most qualified scientists and engineers to the Laboratory. LDRD is one of the Laboratory Director's most important tools for developing and extending the Laboratory's intellectual foundations, for enhancing its core strengths, and for driving its future scientific and technological vitality. R&D that expand the horizons of science and technology are essential to the continued vitality of the Laboratory and its ability to meet future mission needs.

LDRD was established by Congress as a means for DOE laboratories to directly fund creative, innovative basic and applied research activities in areas aligned with their principal missions but not immediately supported by sponsors. In FY 1999, LDRD at Livermore was funded at the allowed annual level of 6%, with a budget of $57 million. In FY 2000, funding has been reduced to 4% due to enacted legislation.

A Mission Focus. LDRD funds are reinvested in the mission areas of sponsoring programs and in R&D projects that align with the strategic vision of the Laboratory. Accordingly, Livermore's LDRD portfolio has a strong emphasis on national security. Each year, Livermore's proposed plan and requested program funding are evaluated against congressional requirements regarding support of national security programs. Based on our assessments for the past four years and an estimate of the FY 1999 portfolio, national security sponsors of work at Livermore receive an LDRD return than far exceeds the 6% investment—over 90% of the Laboratory's LDRD projects contribute to our national security missions.

In fact, all sponsors of research and development at the Laboratory draw a return greater than their LDRD investment. Livermore's LDRD portfolio reflects the Laboratory's focus on its special capabilities, which are applied to multiple mission areas, and on advancing those areas of science and technology to simultaneously address a number of enduring national needs. Many LDRD projects advance capabilities that are important to more than one mission area—for example, ASCI-scale computing, fundamental materials science, advanced sensors and instrumentation, diode lasers, and geoscience.

Program Thrusts

Livermore's LDRD Program has three major components: Strategic Initiatives, Exploratory Research, and the Laboratory-Wide Competition. In FY 1999, about 23% of the funding was invested in Strategic Initiatives, about 71% in Exploratory Research, and about 6% in the Laboratory-Wide Competition.

Strategic Initiatives. Strategic Initiatives are selected on the basis of their alignment with the Laboratory's strategic directions and long-term vision. Proposals for these projects are responsive to the R&D needs of at least one of the Laboratory's five strategic councils: the Council on National Security, the Council on Energy and Environmental Systems, the Council on Bioscience and Biotechnology, the Council on Strategic Science and Technology, and the Council on Strategic Operations. Strategic Initiatives are usually more challenging than projects in the other categories and typically entail the efforts of 5- to 10-person multidisciplinary research teams.

Exploratory Research. Exploratory Research proposals are submitted by the directorates, who first review the proposals to ensure their alignment with the directorate's strategic R&D requirements. The selection process for Exploratory Research projects weighs each proposal's ability to attract and develop young scientists, maintain the scientific and technological competence of the Laboratory, further the organization's strategic vision, and reach academic and industrial communities.

Laboratory-Wide. The Laboratory-Wide Competition provides all members of the Laboratory staff the opportunity to pursue their own creative ideas for one to three years. In this competition, the winning innovative projects further the missions of the Laboratory but are not required to pass a line-management filter.

Recent Accomplishments

Livermore's LDRD Program has been very productive since its inception in FY 1985, with an outstanding record of scientific and technical output. The program continues to provide many far-reaching scientific and technical accomplishments, which are described in detail in the Laboratory's LDRD annual reports (UCRL-LR-113717-98 for FY1998). The FY 1999 report is in preparation.

National Security Support. The Laboratory's national security mission—stockpile stewardship of U.S. nuclear weapons and nonproliferation and counter-proliferation of weapons of mass destruction—provides a focus for Livermore's LDRD portfolio. An overview of LDRD support to national security programs at all three DOE Defense Program laboratories (Livermore, Los Alamos, and Sandia) is presented in *Laboratory Research and Development: Innovation and Creativity Supporting National Security* (Los Alamos publication LALP-96-147, April 1997). Highlights from the FY1998 LDRD program include:

- *Synthesis, Characterization, and Formulation of New Insensitive High-Performance Explosive Molecules.* Using LDRD funding, Livermore is accelerating the development of new high-performance, enhanced safety explosive molecules. By combining advanced quantum-chemistry calculations with aggressive synthesis of promising candidate molecules, we are making a major advance in the development of insensitive high explosives that could improve the safety of the weapons stockpile and have far-reaching DoD applications. To date, this unique approach has been used to design and synthesize three promising candidate molecules and to predict their stability and safety.
- *Proton Radiography Research.* Laboratory researchers supported by LDRD have been exploring the fundamental science underlying the use of high-energy protons as radiographic probes to image nuclear explosives. This is a collaborative effort with groups at Los Alamos (also supported by LDRD). In addition, ideas have been explored to reduce the costs of a proton radiography facility and to examine the technique's potential for advanced hydrodynamic testing as part of the Stockpile Stewardship Program. LDRD has also supported a study to explore the use of available accelerator resources at other DOE laboratories (e.g., Brookhaven and Fermilab) to construct a proton radiography accelerator facility at a site

that could support a hydrotest experimental program.

Awards and Recognition. Laboratory scientists and the research funded by LDRD continue to garner national recognition. For example, the *1998 Excellence in Fusion Engineering Award*; one of the Top 50 R&D Stars by *Industry Week* magazine; and recently, the American Physical Society (APS) selected the Laboratory's results on Petawatt and FALCON lasers as two "dramatic advances in laser/matter interactions" to be highlighted at the APS centennial meeting in March 1999.

In addition, many patents and R&D 100 Awards from *R&D Magazine* have been earned for innovative technologies developed through LDRD-funded research. In FY 1998, 39 of the Laboratory's 78 patents were LDRD-based, and in FY 1998, four of the seven R&D 100 Awards given to Livermore scientists by *R&D Magazine* were based on their LDRD research:

- A computer-aided software-simulation tool was developed for optimizing plasma-assisted manufacturing and could find uses in the semiconductor industry.
- The High-performance Electromagnetic Roadway Mapping and Evaluation System, or HERMES, is a high-resolution, radar-based mobile inspection system for detecting and mapping structural defects.
- A new optical dental imaging system was created to noninvasively image internal tooth and soft tissue microstructure for dental applications.
- A two-color fiber-optic infrared sensor measures temperature and emissions for medical and industrial applications.

Student Support. In addition, LDRD projects provide valuable support for student and postdoctoral research—67 students and 63 postdoctoral fellows in FY 1998. The participation of these scholars-in-training adds vitality to the Laboratory's R&D efforts and provides a pool of talented prospects as future career scientists and engineers.

Long-Term Benefits. By its nature, research may progress for many years before the full impact of an R&D project is realized. In 1998, several previously funded LDRD activities achieved major successes that have been broadly reported in the scientific communities as major scientific accomplishments:

- Research leading to the Extreme Ultaviolet (EUV) Lithography cooperative research and development agreement (CRADA). LDRD-funded research in the 1980s provided much of the basic capabilities to enable the Laboratory to be a major player in a $250-million CRADA with the leaders in semiconductor manufacturing.
- Biological Weapon Agent Detection and Identification. In the case of a terrorist attack or on the battlefield, lives may depend on quick determinations of whether biological agents have been used. LDRD-funded research led to the development of two highly portable and extremely sensitive technologies that are currently undergoing further development under DOE programmatic sponsorship.
- Environmental Cleanup Technologies. For many years, LDRD has funded research projects to identify better methods for cleaning up soil and groundwater contamination. The program contributed to the development of two technologies, dynamic underground stripping and hydrous pyrolysis/oxidation, which have been very successfully demonstrated in Visalia, California. Currently, these technologies are being used for site cleanup at two major DOE facilities, the Portsmouth Gaseous Diffusion Plant in Ohio and the Savannah River site in South Carolina.

3.4 Partnerships and Collaborations

Many Livermore research and development activities are executed in partnership with industry, academic institutions, and other laboratories. As mentioned in Section 3.3, our emphasis on programmatic partnerships and collaborations aligns the science and technology objectives in the DOE Strategic Plan. These objectives are:

- To develop the science that underlies DOE's long-term mission.
- To deliver leading-edge technologies that are critical to the DOE mission and the nation.
- To improve the management of DOE's research enterprise to enhance the delivery of leading-edge science and technology at reduced costs.
- To assist in the government-wide effort to advance the nation's science education and literacy.

Program Thrusts

Partnerships That Create New Capabilities. We *deliver leading-edge technologies* and *contribute to DOE's management of its laboratories* as an integrated system through partnerships with industry and other laboratories. Partnering has been important at the Laboratory ever since our establishment as part of the University of California and the early days of supercomputer development to meet the needs of the weapons program. It will play an even more significant role in the future. Partnering activities will span a wide range—from very-large-scale strategic alliances and "virtual laboratories" to licensing of individual technologies, academic research, and support for the small business community. Partnerships and collaborations help us accomplish our programmatic goals more efficiently and cost effectively. We also work with others to share expertise and make available research capabilities.

Effective Academic Collaborations and Science Education Programs. The Laboratory also partners with universities and *advances the nation's science education and literacy* through academic collaborations and science education programs. As a part of the University of California and as a DOE national laboratory, Livermore shoulders significant science education responsibilities. By making the Laboratory's research facilities and staff accessible to the academic and industrial communities, we provide valuable opportunities to visiting researchers while we strengthen our science and technology base. We are home to several University of California scientific research institutes and other centers that support hundreds of ongoing projects with faculty, post-doctoral fellows, and graduate students. We also help train the nation's next generation of scientists and engineers through our science and technology outreach programs that span every educational level.

3.4.1 Partnerships with Industry

Livermore is committed to promoting partnerships with U.S. businesses and industries. We anticipate that the Laboratory's partnerships and alliances with industry will continue to grow. We work with U.S. companies for various reasons and use a variety of partnering mechanisms. Most importantly, we form partnerships with industry—often through procurements—to acquire mission-critical capabilities. Other partnerships, such as our participation in a consortium to develop advanced technologies to manufacture computer chips, enhance critical capabilities at the Laboratory that are needed for our national security mission. Finally, the areas of environmental remediation and health care provide examples where we "spin off" for public benefit Laboratory-developed technologies through mechanisms such as cooperative research and development agreements (CRADAs) and licensing. (See Table 3-2, Laboratory interaction with industry, FY 1993–1998.) In FY 1998, Livermore had 90 active licensing agreements, reported 163 inventions, applied for 109 patents, and was issued 78 patents.

Livermore's Industrial Partnering and Commercialization (IPAC). This office facilitates many of our interactions with industry. IPAC provides information on licensing, cooperative research, and other opportunities for businesses to benefit from technology transfer, and it negotiates the contracts that govern these relationships.

The IPIPI Committee. The Intellectual Property and Industrial Partnering Issues (IPIPI) Committee was formed in January 1997 to resolve several important Laboratory–industry working relationships and personnel issues related to patents and licensing income, equity holdings, and conflict of interest. IPIPI's principal focus in 1998 was to establish Laboratory policies regarding distribution of income generated by licensed inventions and the acceptance of equity as partial compensation for licensing intellectual property. In addition, a Conflict of Interest Review Committee was established to make sure that related Laboratory policies are

Table 3-2. Laboratory interaction with industry, FY 1994–1999.

Type of interaction	FY 1994	FY 1995	FY 1996	FY 1997	FY 1998	FY 1999	Total
Licenses of Laboratory							
patents and copyrights	36	59	60	65	36	35	291
Royalties (in $M)	0.6	1.1	1.1	2.4	2.3	2.2	9.7
DOE (TTI) CRADAs							
(number active)	84	114	85	55	15	6[a]	359
DOE funding (in $M)	51.1	55.5	52.3	19.5	5.0	2.5	185.9
Lab-funded CRADAs							
(number active)	10	20	26	24	19	24	123
Lab/DOE funding (in $M)	3.2	2.9	3.4	4.4	3.4	3.2	20.5
Industry-funded CRADAs							
(number active)	10	12	22	34	28	33	139
Industry funds-in[b] (in $M)	4.3	6.8	4.9	17.8	29.2	34.5	97.5
Work-for-others projects							
with industry (number active)	–	41	56	85	90	113	385
Industry funds-in (in $M)	–	2.7	3.6	3.4	9.1	8.1	26.9
Other partnerships							
(AVLIS) (number active)	1	1	1	1	1	1[c]	6
Industry funds-in (in $M)	38	48	83	76	90	60	395
Lab SBIR Projects							
(awards made)	–	16	5	3	5	2	31
Industry funds-in (in $M)	–	0.3	0.1	0.2	0.2	0.5	1.3
Spin-off companies (number)	2	3	2	4	3	1	15

[a]At end of FY 1999
[b]Industry funds-in is the funding provided by industry sources to support Laboratory activities.
[c]AVLIS was canceled during FY 1999 (see more information in text).

clearly articulated, widely understood, and followed.

Partnering Mechanisms and Activities

Partnerships through Procurement. Livermore has always pursued industrial partnering through its procurement strategy. To cost effectively acquire the state-of-the-art technologies needed for our major research and development programs, we continually interact with private industries to understand their capabilities and products so that we can make informed decisions. (See Table 3-3, Small business and disadvantaged procurement.)

For example, over 75% of the total funding for construction of the National Ignition Facility will go to U.S. companies, including high-technology firms producing optical components. In some cases, Livermore's programmatic needs actually spur the development of new businesses or new product lines in existing companies. Advances in state of the art may be developed here and transferred to a commercializing partner or developed by the company to meet our requirements in order to generate a production-scale source of equipment, instrumentation, or components for some of our larger experimental facilities.

In the Accelerated Strategic Computing Initiative (ASCI), the three DOE national security laboratories, industry, and academia will drive computer advancements and refinements of prototype machines to meet DOE Stockpile Stewardship computational requirements. These increasingly capable supercomputers initially purchased by the laboratories from U.S. industry will, in turn, help ready the companies for the wider marketplace. Table 3-2 shows our interactions with industry for years 1994 through 1999.

Partnerships through CRADAs. We also work with U.S. industry through a variety of cooperative research and development agreements (CRADAs) in which intellectual property rights are negotiated. Many CRADAs were initiated in the mid-1990s with funding from what evolved to the DOE's Technology Transfer Program (TTP). As the program winds down, Livermore's CRADAs are increasingly funded either as Laboratory-funded (cooperative efforts on technologies we vitally need) or as funds-in projects (industry backing for cooperative efforts).

Table 3-3. Small, Disadvantaged and Women-Owned Business Procurement FY 1998 and FY 1999 (BA in millions of dollars).

	FY 1998	FY 1999[a]
Procure from small disadvantaged businesses	43.9	45.0
Percent of annual procurement	12.1%	15.9
Procurement from small women-owned business	25.2	22.9
Percent of annual procurement	7.0	8.1
Socioeconomic baseline on which the achievements were based	$362.0	283.7

[a]Figures as of November 29, 1999.

One major funds-in CRADA is a project to develop technologies to produce smaller, more powerful computer chips. Researchers from the Livermore, Sandia, and Berkeley national laboratories have formed a Virtual National Laboratory that is working with an industrial consortium including Intel, AMD, and Motorola as major partners. Our work focuses on the use of extreme ultraviolet lithography (EUVL) as a means for etching ultrathin patterns into silicon chips. EUVL technology relies on Livermore expertise in multilayer coating technology and ultraprecision optics metrology to create optical systems that are capable of imaging at wavelengths in the 13-nanometer spectral region.

Licensing Agreements. Through licenses, Livermore grants permission for commercial and noncommercial access to reproduction, manufacture, sale, or other exploitation and use of Laboratory-developed intellectual property. As an example, Southern California Edison and the Laboratory jointly issued a press release announcing exceptionally effective environmental cleanup results. The project used the Laboratory's dynamic underground stripping technology to clean up groundwater contamination at a site previously used to treat power poles with preservatives such as creosote at Visalia, California. Dynamic underground stripping and important auxiliary technologies were licensed to SteamTech Environmental Services to perform the cleanup operations. In the first nine months of use, the process removed or destroyed in place an amount of contaminants that would have required more than 1,000 years with traditional pump-and-treat.

Other Partnering Activities. The Laboratory also engages in industrial work-for-others (WFO) and a variety of small business programs. WFO agreements provide non-DOE organizations with access to highly specialized or unique DOE facilities, services, or technical expertise. Our small business activities include Small Business CRADAs, Small Business Technical Assistance, and participation in the Small Business Innovative Research Program (SBIR) and the Small Business Technology Transfer Program (STTP). Finally, Laboratory has three designated user facilities that industrial partners may use for research, testing, and development of prototypes. They are the Livermore Center for Advanced Manufacturing and Productivity (LCAMP), the Livermore User Facility for Inspection and Characterization (LUFIC), and the Virtual Laboratory Testbed (VLT).

3.4.2 Teamwork with Other Laboratories

We are working with other national laboratories to coordinate and integrate programmatic efforts to provide the best scientific and technical capabilities for the dollars invested. Livermore's collaborative activities are increasing through participation in integrated national programs, such as the Stockpile Stewardship Program and the Joint Genome Institute. Collaborations include the design, construction, and shared use of major research facilities such as the National Ignition Facility at Livermore and the B-Factory at the Stanford Linear Accelerator Center.

Factors critical to the success of these team efforts include effective high-level DOE leadership, well-defined program goals and deliverables, complementary capabilities among the national laboratories, confidence in each other's commitment and performance, and a healthy competition of ideas within a collaborative framework.

3.4.3 University Collaborative Research

Individual collaborations between Livermore scientists and university faculty and students have taken place since the Laboratory was founded. Our research collaborations with university faculty and students are designed to blend basic research with applied researchers. The collaborations provide effective ways for unique Laboratory facilities and expertise to be made available to the broad U.S. research community. Table 3-4 shows Livermore's collaborations with universities from FY 1997 through mid-FY 1999.

The University Relations Program. The Laboratory's University Relations Program encourages and expands research collaborations between LLNL and universities, other research organizations, and industries. The program contributes to the intellectual vitality of all the partners through basic and applied research collaborations. By facilitating the flow of ideas and people between institutions and by making our unique facilities and expertise available to students and faculty, we address problems that are of interest to the broad U.S. research community and that help solve complex problems of importance to the nation. In one current project, we are in the process of establishing a database to allow Livermore staff to access potential University resources, recruit students, or find new partners for continuing or expanding joint research projects. In another, the University Relations Program also oversees the

Table 3-4. Laboratory–university collaborations FY 1997 to FY 1999.[a]

Type of collaboration	FY 1997	FY 1998	FY 1999
Collaborations with University of California (total number)	461	499	419
UC faculty	164	202	175
UC research staff	65	87	79
UC students	232	210	165
Collaborations with other California universities (total number)	75	78	85
Faculty	33	32	51
Research staff	12	10	12
Students	30	36	22
Collaborations with non-California universities (total number)	385	415	537
Faculty	201	204	314
Research staff	57	63	118
Students	127	148	105

[a]University and college faculty, research staff, and students involved in collaborations with the Laboratory at Livermore, at their home institutions, or both. The method for calculating the collaborations has been improved to more consistently report the activities of participants, and thus there is some difference between this year's table and prior Institutional Plans.

Laboratory's science and technology education efforts (see Section 3.4.4). We help train the nation's next generation of scientists and engineers through our outreach programs that span every educational level. The Laboratory also benefits by enlarging the pool of talent and raising awareness about Livermore and its national security mission—our continuing success depends on recruiting and retaining quality staff.

Livermore–University of California Research Institutes

Several Livermore–university institutes have been established in specific subject areas, setting a focus for collaborations with the nine University of California campuses as well as with many other universities. They provide a hospitable environment for visiting students and faculty. These institutes advance the strategic goals of the Laboratory by aligning subject matter with expertise needed to execute Laboratory programs. The institutes include:

Institute of Geophysics and Planetary Physics (IGPP). The Livermore branch of IGPP (a Multi-Campus Research Unit) runs the Astrophysics Research Center, which carries out a significant research program and manages the astrophysics part of the University Collaborative Research Program (UCRP). The Center for Geosciences in IGPP promotes UC collaborative research in the earth sciences. The center's research emphasis is on the physics and chemistry of Earth, including seismology, geochemistry, experimental petrology, mineral physics, and hydrology.

Center for Accelerator Mass Spectrometry (CAMS). Processing about 20,000 samples per year with its extremely sensitive measurement capability, CAMS supports research programs that range from archaeological dating to biomedical research, and from global climate change to geology. The capabilities of CAMS are available to all qualified users under standard DOE procedures. Some 75 service contracts are currently in place with nonprofit foundations, non-DOE agencies, and private corporations.

Institute for Scientific Computing Research (ISCR). A major objective of the ISCR is to encourage original work that has the potential for significant impact in computing research and reinforces the scientific and technological strengths of the Laboratory. ISCR's educational outreach is accomplished in part through grants where the funds support graduate students and postdoctoral researchers.

Institute for Laser Science and Applications (ILSA). ILSA is a center of excellence at Livermore in the area of laser plasma physics. We focus on high-peak-power lasers and advanced ultrahigh-speed diagnostics. The University of California, principally the Davis and Berkeley campuses, is a strong collaborator in ILSA. Collaborations with other universities across the country are already extensive and will continue to expand.

Materials Research Institute (MRI). MRI promotes the highest-quality materials research and innovation through collaboration between universities and the Laboratory. We are concentrating on projects that highlight and use our unique capabilities, such as the Nova laser, the Electron Beam Ion Trap (EBIT), the Positron Microprobe, and Livermore's high-pressure shockwave and diamond-anvil-cell facilities.

Other University Interactions

The Department of Applied Science. The Department of Applied Science (DAS), a part of the College of Engineering at the University of California, Davis, with facilities at both Davis and Livermore, offers a limited number of temporary positions to selected UC Davis graduate students who then work in one of the Laboratory's major research facilities while conducting thesis research related to the programmatic research. In 1998, after a comprehensive review of the UC Davis DAS program, the Livermore student fellowship program was broadened beyond applied science and computer science to include all relevant UC Davis departments.

University of California Directed Research and Development (UCDRD). Other collaborative activities among the three UC-managed DOE national laboratories are supported by two funds established by the UC/DOE management contract. The UCDRD Fund, with up to $11 million allocated each year to the laboratories, is available to support research activities at the discretion of each laboratory director. Livermore uses UCDRD funds for strategic investments at the Laboratory and for integrating support with other UC collaborative efforts. The other fund, a $3-million Complementary and Beneficial Activities (CBA) Fund, was established specifically to support collaborative research efforts through the Campus–Laboratory Collaborations (CLC) Program.

Lawrence Livermore Fellowships. Among the research opportunities offered by the Laboratory is a newly established (in 1998) Lawrence Livermore Fellowship, a distinguished postdoctoral program. The Fellows have world-class resources to support their research. Fellowships are awarded only to candidates with exceptional talent, credentials, scientific track records, and potential for significant achievements. The Fellows are expected do original, independent research in one or more aspects of science relevant to the competencies of the Laboratory.

PETE. The Partnership for Environmental Technology Education (PETE), established at Livermore in 1991 and now a national nonprofit organization, fosters training in environmental technologies at the community college level. PETE links the 600 participating colleges with the technical resources of DOE, DoD, EPA, and NASA laboratories, which assist in curriculum development for training technicians in environmental and hazardous materials.

University of California, Merced

The University of California is developing plans to open a tenth campus in Merced, California, in 2005. The new campus, with 5,000 students anticipated by 2010, is expected to have an affiliation with Livermore in areas of science and engineering. UC Merced planners have been meeting senior managers at the Laboratory to identify potential disciplines for building centers of excellence and hiring faculty. Possible focus areas include environmental sciences (environmental restoration, water resources, and nonpolluting transportation), computer and information science (supercomputing and bioinformatics), engineering (bioengineering and other advanced technologies), and optical science/laser science and applications.

3.4.4 Science and Technology Education Programs

The Laboratory's Science and Technology Education Program (STEP) serves as a resource and partner to students, teachers, and university faculty, making available Livermore's world-class facilities, scientists, and staff. Through STEP, Livermore helps to contribute to the nation's development of a highly skilled, diverse workforce that will enhance our ability to conduct the Stockpile Stewardship mission. STEP also furthers scientific and technical literacy.

During FY 1998, 104 high school, 114 undergraduate, and 44 graduate students directly participated in STEP projects having a summer, semester, or full academic year duration. By adding to their skills, knowledge, and abilities, students in STEP advance along the path to careers in science.

STEP is involved in the science education listed activities listed in Table 3-5. FY 1998 accomplishments of the 19 project areas are discussed in the *STEP FY 1998 Annual Report* (at http://education.llnl.gov/report.html). These student and teacher programs and educational outreach programs support four goals:

- Provide research opportunities at the Laboratory for undergraduate and graduate students.
- Exploit new uses of current technology, such as the Internet, through educational activities that relate to and support the DOE scientific mission at the Laboratory.
- Support teacher skill development and curriculum improvement in technologies of special interest to the Laboratory.
- Increase science literacy through educational outreach, with a special emphasis on local and regional needs.

Student and Teacher Programs

A principal source of funding for many STEP Student and Teacher Programs is DOE Defense Programs. Projects focus mainly on the first three goals, with the overarching objective of increasing the quantity and capabilities of college students entering careers that are important to the intellectual capability required by the DOE national security mission. Projects encompass science fundamental to the Defense Programs mission, such as the Accelerated Strategic Computing Initiative and the National Ignition Facility. Examples include:

Actinide Sciences Summer School Program. The Actinide Sciences Summer School Program is an educational opportunity for undergraduate and graduate students arranged through the Glenn T. Seaborg Institute for Transactinium Science

Table 3-5. Livermore participation in Science Technology Education Program (STEP) activities in FY 1999.

Student and Teacher Programs	Educational Outreach Programs
Global/National Security Cooperative Program (NSC)	Math Challenge
HBCU/HSI/MI Research Collaboration Program (RCP)	Fun with Science (FWS)
Military Academy Research Associates (MARA)	Expanding Your Horizons (EYH)
Undergraduate Research Semester (URS)	Future Scientists and Engineers of America (FSEA)
Actinide Sciences Summer School Program (ASSSP)	Science on Saturday (SOS)
High-Performance (ASCI) Computing and Visualization	Tri-Valley Science and Engineering Fair (TVSEF)
National Education Supercomputer Program (NESP)	Explorer Post
Critical Issues Forum (CIF)	Career Speakers
Laser Curriculum (LSOC)	
Centers for Excellence in Student Research (CESR)	
Technology Resource Center	

(GTS–ITS) at the Laboratory. The program provides an opportunity for students to interact with practicing scientists in their laboratories and gain a broader sense of how radiological science is done. Activities encourage students to pursue scientific careers and give them exposure to the actinide sciences so that they may consider careers in these fields, which are the heart of the DOE mission.

Historically Black Colleges and Universities (HBCUs) Research Projects. Initiated in 1994, our Research Collaborations Program (RCP) establishes scientific collaborations between accomplished research faculty at HBCUs and principal investigators at the Laboratory in areas of core competency. The program provides unique research opportunities for participants and spins back to Livermore additional expertise and staffing for basic research efforts through the involvement of professors, postdoctoral researchers, graduate students, and undergraduate students.

Military Academic Research Associates (MARA). The MARA program provides opportunities for students at the U.S. military academies to spend their summers participating in national security research activities at the Laboratory.

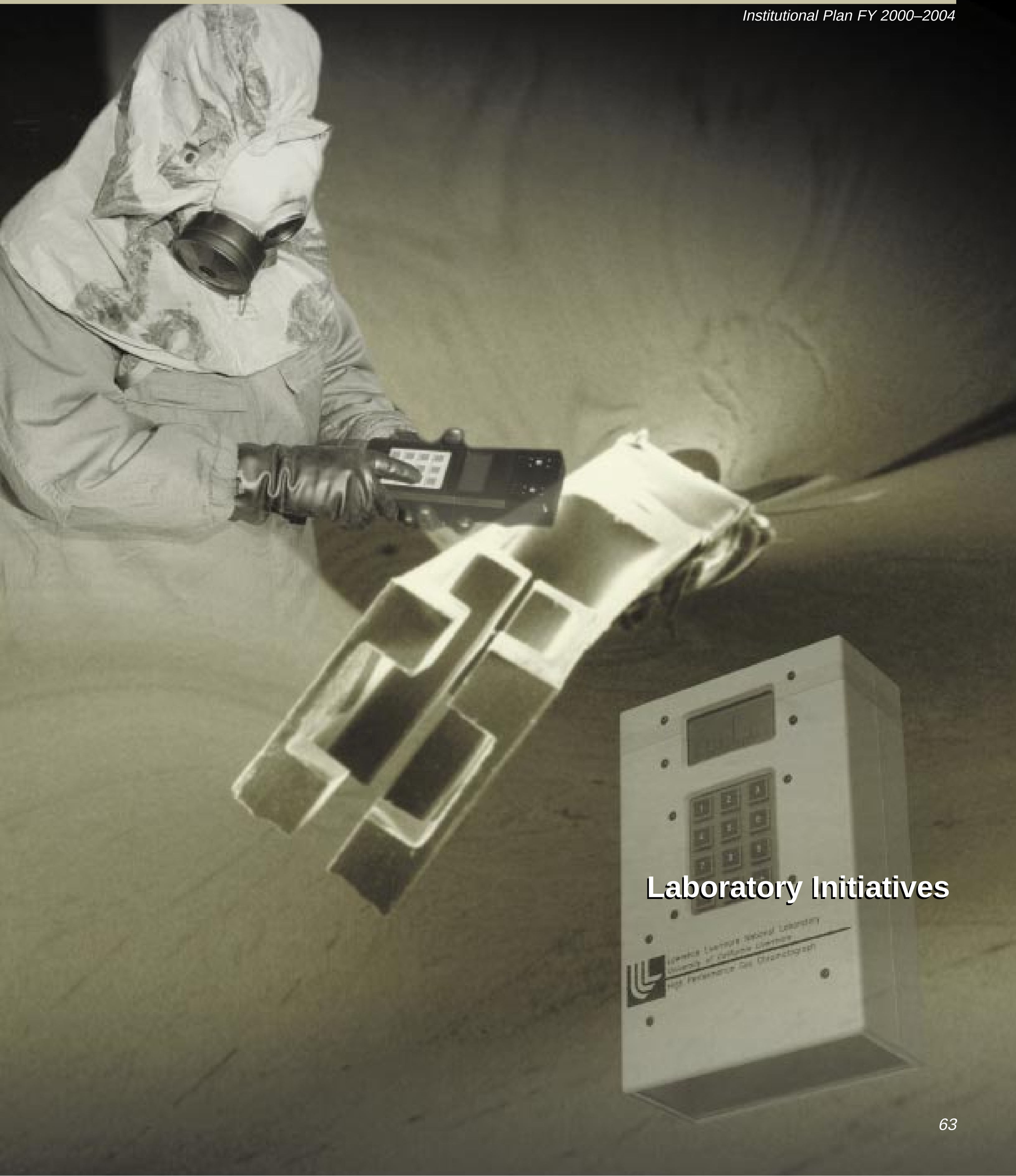
The Undergraduate Research Semester (URS). URS is an opportunity for undergraduate and pre-grad-school students to conduct research at one of the DOE Defense Programs laboratories. The program offers students 16 weeks of “hands-on” research under the guidance of Laboratory scientists and engineers.

The Technology Resource Center. In day-long training sessions, Technology Resource Center instructors help busy teachers to explore the Internet for material that can be used to enhance science education in their classrooms. In 1998, over 2000 teachers—and indirectly about 240,000 students—have participated in this program.

Educational Outreach

Other activities—largely directed at educational outreach—are internally funded through the General and Administrative Distributed Budget. The overarching objective is to help pre-college students become aware of the role of science in our nation’s future, and promote science and technology careers. Managed through local and regional partnerships, these science literacy activities play an important role in creating future scientists, engineers, and technicians, especially in potential careers of direct interest to the Laboratory. They also stimulate greater interest in science and technology among students, teachers, and administrators, as well as the general public.

SECTION 4



Laboratory Initiatives

The Engineering Directorate's Microtechnology Center features "Xtreme" capabilities in microfabrication, microstructures, microfluidics, and photonics. Shown here, left to right: the Laboratory's portable PCR performs real-time DNA analysis in the field through the use of polymerase chain reaction, a microgripper the size of two grains of salt is used as an electromechanical microtool for endovascular therapy or remote handling of small parts in extreme environments, and a miniature "Xtremely" fast low-power gas chromatograph identifies liquid or gas species with detection sensitivities as high as parts per billion.

THE following initiatives are proposed as major additions to existing programs or as new directions within our missions. We have also included information about major, ongoing Stockpile Stewardship initiatives—the National Ignition Facility, the Accelerated Strategic Computing Initiative, Enhanced Surveillance, and the Advanced Design and Production Technology Program.

For new initiatives, the programs and budget figures are provided for consideration by the Department of Energy. The detailed Program Resource Requirements tables do not reflect the growth in resource requirements needed to pursue the initiatives. Their inclusion in this Institutional Plan does not imply DOE approval of or intent to implement the proposal. Listed after each initiative title is its Budget and Reporting Code designation.

4.1 Assistant Secretary for Defense Programs

4.1.1 National Ignition Facility (DP)

The National Ignition Facility (NIF) is a vital element of DOE's Stockpile Stewardship Program. The NIF will provide the capability to conduct laboratory experiments that address the high-energy-density physics and thermonuclear fusion issues important to the safety, reliability, and performance of the stockpile.

The NIF provides unique capabilities in the laboratory. The ignition and burn of an inertial fusion capsule in the laboratory will produce extremely high temperatures and densities that only occur in the sun and nuclear weapons. Other specially designed targets will be used to test important issues of weapon physics. These experiments will provide critical data for understanding weapons physics and testing advanced codes being developed for modeling nuclear weapons. In addition, NIF will be important for training new stewards of the U.S. nuclear weapons stockpile. NIF also can be used to perform studies on the effects of nuclear weapons output. In addition, the NIF will become a unique and valuable laboratory itself for experiments relevant to many areas of basic science and technology.

A complementary long-range DOE program goal is to generate electric power using inertial confinement fusion (ICF). The NIF will be used to establish the requirements for driver energy and target illumination for high-gain fusion targets and to develop materials and technologies needed for civilian fusion power reactors.

The NIF is the most recent in a series of high-powered lasers built at Livermore. NIF will have 192 beams, each consisting of 40-centimeter-square aperture neodymium-doped glass laser and optics system. These beams will focus inside a 10-meter-diameter target chamber with associated controls and diagnostics. The project includes constructing a new Laser and Target Area Building to house the laser and target chamber. In addition, an Optics Assembly Building is being constructed for processing and refurbishment of optics.

The modular design of the laser allows for activation of the facility in a sequence that best supports the Stockpile Stewardship Program. This transition to operation could allow NIF to perform experiments in support of stockpile issues before the end of the project should this feature be desired.

The NIF is presently being built at the Laboratory by a multilaboratory team led by Livermore. Planning for NIF began in January 1993 after DOE approved a Key Decision Zero, which established mission need. The Conceptual Design Report (CDR) for the NIF was completed in May 1994. On October 21, 1994, the Secretary of Energy issued a Key Decision One for the NIF, which initiated the line-item funding cycle for the project and the advanced conceptual design. Title I design of the conventional facilities and special equipment began in December 1995 following the Secretary's determination that the NIF construction supports the U.S. nonproliferation objectives (Key Decision One Prime). The Title I design was completed and comprehensively evaluated by a team of independent reviewers to determine the NIF's technical readiness to proceed with the Title II detailed engineering phase of the project. This review, completed November 22, 1996, identified no issues that precluded proceeding; the project requested and DOE granted approval to initiate final Title II design and long-lead-time procurements. The NIF project received approval to begin construction (Critical Decision Three) on March 7, 1997, and conventional facilities are scheduled to be completed at the end of FY 2000. An important milestone was reached in June 1999 with the dedication of NIF's 150-ton target chamber and its relocation into the chamber bay.

In September 1999, Secretary of Energy Bill Richardson ordered a series of actions to address schedule and cost issues that have arisen with the construction of the NIF. At the same time, Laboratory Director Bruce Tarter made significant changes in the NIF management team at Livermore. In the announcement of the six actions to be taken, Secretary Richardson stated, "The problems with NIF are not technological—the underlying science of the NIF remains sound."

One of the Secretary's actions led to his appointment in November 1999 of a

Striving to Meet the Laboratory's Milestones by 2001

Laboratory Activities	Milestones
Section 4 Initiatives DOE Program Sponsors: 4.1 Assistant Secretary for Defense Programs 4.2 Office of Nonproliferation and National Security 4.3 Office of Science 4.4 Assistant Secretary for Energy Efficiency 4.5 Multiple Program Offices	• The National Ignition Facility building complex is complete, and laser support equipment is being installed. • The 10-teraops computer for the Accelerated Strategic Computing Initiative is fully operational for stockpile stewardship calculations, and Livermore is helping to drive all aspects of high-performance computing. • The Laboratory is providing technology and capabilities to protect the United States from nuclear, chemical, biological, and other emerging threats to national security. • The Joint Genome Institute has exceeded its sequencing goals, and the Laboratory has built support for follow-on efforts in functional genomics and structural biology. • Livermore has expanded initiatives in nuclear materials stewardship, Visalia clean-up technology, and global climate modeling.

task force of the independent Secretary of Energy Advisory Board (SEAB) to review the NIF. The NIF Laser System Task Force, chaired by Dr. John McTague, formerly vice president for technical affairs of Ford Motor Company, was asked to provide advice on the option to complete the facility, recommend a technical course of action, and deliver its recommendation as quickly as possible.

In addition, a special review panel of the University of California President's Council examined the NIF project and issued its findings in November 1999. The panel provided a series of recommendations that will be helpful in strengthening the NIF project and putting it on a course for successful completion. UC and the Laboratory are making improvements consistent with the report's findings and recommendations.

See Table 4-1 for construction resources requirements.

To Technical Base and New Construction for Stockpile Stewardship, see Section 2.1.4

4.1.2 Accelerated Strategic Computing Initiative (DP)

The Accelerated Strategic Computing Initiative (ASCI) is a program that greatly extends the computational capability of DOE Defense Programs (DP). The initiative's goal is to provide a robust computer-based capability for assuring the safety, reliability, and performance of the U.S. nuclear stockpile in an era without nuclear testing. ASCI simulation capabilities will integrate experimental data from above-ground test facilities, archival nuclear test data, and improved scientific understanding to provide predictive simulation capabilities needed to support decisions about the enduring stockpile.

To succeed, the ASCI program must create leading-edge computational modeling and simulation capabilities based on advanced simulation codes and high-performance computing technologies. A new generation of weapons simulation codes will combine advanced fundamental physics models, much greater spatial resolution, and the ability to model weapons behavior in three dimensions. Using these codes will require computers hundreds to thousands of times more powerful than the best available today. The three DP laboratories are working with industrial partners to accelerate the development of new High Performance Computing Platforms with the needed levels of capability.

In response to DOE priorities, Livermore is:

- Developing three-dimensional simulation codes with high resolution and high-fidelity physics simulation codes.
- Applying the expertise of experienced nuclear weapon scientists and engineers to validate these models for behavior, performance, safety, reliability, and manufacturing scenarios; and training a new generation of experts in the process.
- Establishing and following a collaborative acquisition path to systems with computing power much greater than 10 trillion floating-point operations per second (10 teraops) and the necessary infrastructure of utilities, storage, networks, and visualization.
- Developing a distributed-at-a-distance computing numerical test and assessment site to allow access to advanced ASCI computers by designers at all three laboratories.

In addition to simulation code development and verification and validation efforts, Livermore, working with Sandia and Los Alamos, is developing Problem-Solving Environments (PSEs) to accelerate the development and application of the new ASCI simulation codes to the problems of stockpile stewardship by our weapon scientists. Much of this research effort to improve visualization and data management tools is being conducted in collaboration with partners in the National Science Foundation and University Alliances. Key elements of problem-solving environment are advanced code-development tools, very large and fast data storage facilities, and high-speed communication links for both classified and unclassified data. The scientific applications will be generating huge output files, possibly as large as many trillions of bytes from an overnight run, and the scientists must be able to assimilate the information.

A major element of the coming simulation environment is the development of very-high-performance visualization capabilities called Data and Visualization Corridors (or DVCs). We are combining high-performance storage and networking with a visualization architecture that allows interactive exploration of large quantities of data. Tools are being developed to interactively navigate the generated data and select subsets to analyze. Improved visualization of ASCI-generated data is offered by Livermore's new Assessment Theater, a user interface of the DVC. The theater includes state-of-the-art projectors to achieve extremely high resolution and superior image quality on a screen 3,840 $\times$ 3,072 pixels (which will increase to 6,400 $\times$ 3,072 pixels in FY 2000). The Assessment Theater is connected to the Livermore Computing complex via the Laboratory's fiber-optics infrastructure. The theater provides opportunities for weapon scientists to visualize the results of ASCI calculations and for visualization researchers to experiment with capabilities among the best in the world.

A central component of ASCI is the accelerated development of highly parallel, terascale computers in partnership with the U.S. computer industry. The Laboratory retired the first of a sequence of ASCI systems delivered by IBM (the 512-node IBM SP) earlier this year and accepted a far more powerful 320-node Symmetric Multiprocessor-based system called the Technology Refresh System in March 1998. The peak capability of this computer is just over 0.9 teraops. Then, in December 1998, six months ahead of schedule, Livermore took delivery from IBM of the 3.8-teraops Blue Pacific system. The computer is a hyper-cluster of 1,464 nodes hooked together by a multiple-state hierarchical network. Each node is a four-way shared memory multiprocessor with its own operating system and local disk. The system includes 17.3 terabytes of local disk memory and 62.5 terabytes of global disk memory. A 10-teraops successor is planned for 2000. Further increases in capability will require a new computer facility at Livermore, the Terascale Simulation Facility (TSF) (Section 4.1.3).

The high-performance computing technologies that are developed as part of the ASCI program will directly support the nation's technology base. Academic partnerships are also important to ASCI. Livermore is working with five major American universities that are participating in Academic Strategic Alliances Program (ASAP), which is a $250-million

Table 4-1. Resources required for construction of the National Ignition Facility.

Fiscal year	BA in $M[a]
1993	6.0
1994	6.2
1995	6.0
1996	61.0
1997	191.1
1998	229.1
1999	291.0
2000	254.0
2001	TBD[b]
2002	TBD
2003	TBD
Total	**TBD**

[a]Includes Operating Costs, Capital Equipment, and Construction.
[b]To be determined.

initiative to assist the three DOE national security laboratories in meeting ASCI computational science and simulation goals. The participating universities are pursuing very-large-scale applications that collectively drive the development of modeling and computing capabilities.

Table 4-2 shows the resource requirements for the ASCI initiative. This table includes operating dollars that are spent at Livermore (Advanced Applications and Problem Solving Environments) and dollars that flow through Livermore to others (PathForward and Alliances).

To Stockpile Stewardship Campaigns, see Section 2.1.2.

4.1.3 Terascale Simulation Facility (DP)

The Terascale Simulation Facility (TSF) is creating a simulation environment rather than just a very large, but traditional, computer center. The change in concept from "computing" to "simulation" is fundamental. The latter entails the development of a seamless partnership between the ability to generate terascale quantities of data and the ability to assimilate the information and make it accessible to the human eye and mind. The scientific applications being developed today promise an unprecedented level of physical and numerical accuracy. This level of accuracy and a sophisticated supporting environment to visualize simulation experiments are required by ASCI for stockpile stewardship to succeed. Simulation, in this sense, which includes detailed visualization, represents a fundamental conceptual shift that dictates the scope and timeline for the proposed TSF.

Expansion of Livermore's computing power beyond the 10-teraops platform will require such a new facility. The technical objective is to construct a complex to house and coordinate two complementary elements: (1) the most advanced computers available, aggregated in configurations such that their capability, physical size, and power requirements will be unequaled outside the Stockpile Stewardship Program; and (2) tools for the management, transmission, and comprehension of the vast data sets generated, referred to as Data and Visualization Corridors. Plans for the TSF have been developed and a Conceptual Design Report has been approved. The construction project is being initiated with a FY 2000 line-item authorization of $8.0 million and requires $20.0 million in FY 2001. The estimated total cost of the facility is $83.5 million and, with timely funding, The TSF will be completed late in 2004 (see Table 4-3 for resource requirements). About 24,000 square feet of the machine room (or half of the 48,000 square feet planned) will be available and fully equipped to accept an ASCI-scale system as early as August 2002.

Design of the TSF is driven primarily by power and space requirements for future-generation ASCI-scale computers. Between 6 and 8 megawatts are required to run the computer, and cooling needs an additional 4 to 5.5 megawatts. For smooth integration of old system to new system, two floors will be built. Because the computer is expected to be composed of multiple frames with many nodes in each frame and because each node must communicate with a central switch, the underfloor will have to accommodate hundreds of copper and fiber cables yet have enough room for free air flow. The chilled air will be pushed up from the first floor directly into the frames. The air will then be captured in the ceiling of the second-floor computer room and returned through the walls to the basement for cooling and recirculation. The air in the machine room is be exchanged several times per minute. The center is designed to accommodate any computer architecture.

Table 4-2. Resources required for the Accelerated Strategic Computing Initiative (BA in millions of FY 2000 dollars after FY 1999).

Fiscal year	Operating and maintenance cost
1997	46.7
1998	100.9
1999	122.8
2000	132.8
2001	143.1
2002	144.0
2003	144.0
2004	144.0

Table 4-3. Resources required for the Terascale Simulation Facility at Livermore (BA in millions of FY 2000 dollars after FY 1999).

Fiscal year	BA in $M
1997	0.0
1998	0.0
1999	0.0
2000	8.0
2001	20.0
2002	23.0
2003	23.0
2004	9.5
Total	83.5

The building will also house the growing staff of computer and physical scientists who support the computers or work on research and development projects such as the Data and Visualization Corridors (DVCs) necessary for assimilating terascale data sets. ASCI applications use extremely high-resolution (and growing) models—as large as tens of billions of cells—and generate vast amounts of raw data that can overwhelm scientists. DVCs combine high-performance storage and networking with a visualization architecture in a way that allows interactive exploration of large quantities of data. These tools provide opportunities for weapon scientists to visualize the results of ASCI calculations and for visualization researchers to experiment with capabilities that are among the best in the world.

Table 4-3 shows the resource requirements for the Terascale Simulation Facility initiative.

To Technical Base and New Construction for Stockpile Stewardship, see Section 2.1.4.

4.1.4 Advanced Design and Production Technology Program (ADaPT) (DP)

The ADaPT Program is a DOE-complex-wide effort to develop innovative technologies for new processes and practices to enable cost-effective production of stockpile weapon components. The enduring weapons stockpile, as well as workforce skills, will be maintained by a combination of repairs, refurbishments, and as-needed replacements. ADaPT integrates the skills and facilities of the three weapons labs—Livermore, Los Alamos, and Sandia—with the four production plants—Pantex, Y-12, Kansas City, and Savannah River. The ADaPT Program has defined four areas of strategic investment:

- Enterprise integration, through a secure, complex-wide, high-speed digital network.
- Integration of product and process design (concurrent engineering).
- Development and qualification of new, advanced processes for efficient, environmentally benign production.
- Contingency planning, for various scenarios such as major rebuilds.

Livermore is actively involved in each of these endeavors. For example, we developed a femtosecond laser-cutting technology that reduces costs and wasted materials in weapon refurbishment activities. A demonstration of the laser-cutting technology was conducted in an environmentally controlled workstation, designed and built at Livermore in cooperation with Y-12 personnel. The Laser Cutting Workstation (LCWS) at Y-12 is to be used for recovery of high-value components for the W87 Life Extension Program. Laser cutting of high explosives continues to attract significant interest—from DOE and DoD. In particular, the demilitarization of high explosives in various legacy systems is a significant application for the femtosecond laser technology.

Livermore is involved in the cross-complex effort to develop secure internet technologies. Recent demonstrations at Livermore have led to several unique approaches to defining the “need-to-know” access criteria for classified information access via secure internet Web browsers. Most recently, Livermore instituted classified e-mail systems between the Livermore site, Y-12, and Los Alamos. Systems for Web-browser-based interrogation of classified surveillance databases are under development.

Livermore is also engaged in developing advanced processes for manufacturing plutonium and uranium parts that minimize wasted materials and significantly reduce the waste stream. We are working with Y-12 to develop environmentally benign lithium recovery technologies. We are also working with Pantex to develop an advanced process for future production of insensitive high explosive (TATB) that may result in a great cost savings. We are in the process of completing milestones for the development of spin-forming technology for the production of metal parts. This near-net shape technology promises to reduce floor space requirements and costs.

The resource planning for ADaPT at Livermore, based on current planning within DP-20, is shown in Table 4-4. *To Direct Stockpile Work, see Section 2.1.3.*

4.1.5 Enhanced Surveillance (DP)

The Enhanced Surveillance Program (ESP) is a multiyear program aimed at providing stockpile surveillance programs with improved diagnostic tools and predictive capability to determine when refurbishing or remanufacturing weapons materials and components will

Table 4-4. Resources required for the ADaPT Initiative at Livermore (BA in millions of FY 2000 dollars after FY 1999).

Fiscal year	Operating and maintenance cost
1998	9.9
1999	7.9
2000	5.9
2001	7.5
2002	10.0
2003	10.0
2004	10.0

be necessary. The objectives of ESP are to develop tools, techniques, and models that enable us to provide advanced capability to measure, analyze, calculate, and predict the effects of aging on weapons materials and components and to understand these effects as they impact reliability, safety, and performance of weapons that are aged beyond their originally designed lifetimes. The lifetime predictions are intended to allow accurate planning for refurbishment production. ESP techniques are developed using selected enduring and retired stockpile weapon systems. On an annual basis, ESP projects are reviewed with unsuccessful projects being terminated and work on new advanced R&D concepts added.

Activities under this program are carried out at the DOE weapon production plants (the Kansas City Plant, Y-12 Plant, Savannah River Site, and Pantex Plant) and weapons laboratories (Lawrence Livermore, Los Alamos, and Sandia). There is a strong partnership among the labs and production sites to coordinate planning and project selection and to foster teamwork in the conduct of research projects for the ESP. Because an enormous base of data already exists from the many years of core surveillance program studies, it is highly desirable to store and manage this information so that trends in behavior can be readily identified. Accordingly, ESP is also tasked with supporting leading-edge projects for this data-driven activity.

Important efforts under way at the Laboratory are aimed at assessing the lifetime of pits and high explosives. These include an accelerated aging study for pits being carried out with colleagues from Los Alamos. We must understand aging in plutonium and the effect of aging-related changes on the performance of an imploding pit of a stockpiled weapon. Otherwise, we will not be able to accurately estimate the lifetime of weapon pits and determine whether the nation must make costly investments to expand plutonium operations.

We are also pursuing a variety of efforts to improve the sensors and diagnostics used to inspect stockpiled weapons. For example, Livermore is developing high-resolution x-ray tomography for imaging weapon pits, solid-phase microextraction technologies for nonintrusively collecting and analyzing chemicals in sealed weapon components, and high-energy neutron radiography for nondestructively detecting small voids and structural defects in weapon systems. Working with Y-12, AlliedSignal, and Savannah River, we are also pursuing ultrasonic technologies for the nondestructive evaluation of bonds in weapon components and microsensors for evaluation of materials degradation and corrosion in weapon systems. See Table 4-5 for resource requirements.

Table 4-5. Resources required for Enhanced Surveillance ($M).

Fiscal year	Operating and maintenance cost
1998	9.9
1999	16.2
2000	18.2
2001	19.1
2002	19.5
2003	20.5
2004	21.0

To Direct Stockpile Work, see Section 2.1.3

4.1.6 NTS Two-Stage Light Gas Gun—JASPER Facility (DP)

An important experimental technique for determining the properties of materials at high pressures, temperatures, and strain rates is to shock the material by impacting a small sample with a projectile traveling at high velocity and diagnosing the material response. These tests are conducted using gas guns. Currently, the only facility available for performing these tests on special nuclear materials (SNM) is the 40-millimeter, single-stage gas gun located in TA-55 at Los Alamos. This gun can achieve a maximum projectile velocity of about 2 kilometers per second. Much higher projectile velocities are required to fully achieve the desired shocked material conditions. These higher velocities can be achieved by using a two-stage gas gun.

The technology, target design, and diagnostic needs of such a gun are well known; similar guns have been in operation at Livermore, Los Alamos, and Sandia national laboratories for many years. However, SNM cannot be tested in these guns. Members of the shock compression physics groups at these three laboratories have developed the scientific requirements for a shock compression facility using a two-stage gas gun for the study of plutonium and toxic materials at extreme conditions. The initial design will enable projectile velocities of up to 8 kilometers per second, with velocities up to 15 kilometers per second possible with future design modifications. A siting study resulted in a decision to base this technology at the Nuclear Explosives Assembly Facility at the Nevada Test Site (NTS). The project has been authorized for construction.

The Joint Actinide Shock Physics Experimental Research (JASPER)

Facility Project was kicked off in January 1998 by a multiorganizational project team consisting of Livermore, Los Alamos, Sandia, Brookhaven, and DOE/NV. Livermore has responsibility for overall project management, physics definition, engineering, health and safety, and authorization-basis documents. JASPER will be the first nuclear facility at the NTS (Hazard Category 3 nonreactor) and will be operated by Livermore.

JASPER experiments will support the Stockpile Stewardship Program in several ways and are complementary to subcritical experiments also being conducted at NTS. Because of the well-controlled environment of the gas gun, JASPER will provide scientists with more precise equation-of-state data than can be obtained from any other type of experiment. The project is scheduled for completion in 2000, and it is estimated that the laboratories will perform about 25 experiments annually.

To Stockpile Stewardship Campaigns, see Section 2.1.2.

4.2 Office of Nonproliferation and National Security

4.2.1 Activities with Russia and the NIS (NN)

The U.S. is engaged in numerous activities to assist Russia and the other newly independent states (NIS) in protecting their nuclear materials, engaging their nuclear weapons institutes on arms control and nonproliferation issues, and helping former Soviet weapons scientists develop self-sustaining nonweapons and commercial applications of their skills and facilities.

Through the DOE's Material Protection, Control, and Accounting (MPC&A) Program, the U.S. is helping to upgrade the physical protection and material accountancy systems at facilities in the former Soviet Union where weapons-usable nuclear materials are processed, stored, or used. Of the 50-plus MPC&A sites, Livermore has the lead at five: Krasnoyarsk-45, Sverdlovsk-44, Bochvar, Automatics, Chelyabinsk-70. We are also working with the Northern and Pacific fleets of the Russian Navy and with the Murmansk Shipping Company to protect the fuel for their nuclear-powered vessels; these activities involve direct interactions with the Russian Ministry of Defense.

A new thrust in our NIS activities involves work with three of the Russian closed nuclear cities: Snezhinsk (Chelyabinsk-70), Sarov (Arzamas-16), and Zheleznoyarsk (Krasnoyarsk-26). Under the Nuclear Cities Initiative, the three DOE national security laboratories will work with these cities to assist them in finding ways to exploit their technical and scientific strengths to become economically self-sufficient. A specific goal is to create new Russian jobs to correspond to those being lost at these cities as a result of Russia's downsizing of its nuclear weapons complex. Initial projects are in fiber optics (Snezhinsk) and poly-silicon for the computer industry (Zheleznoyarsk); the project with Sarov has not yet been selected.

We also collaborate in international efforts to detect and intercept nuclear smuggling. The Second Line of Defense program focuses on Russian borders, and additional counter-nuclear smuggling activities focus on other international borders. Laboratory expertise in nuclear detection, nuclear forensics, nuclear material protection and accounting as well as our operation of the Communicated Threat Credibility Assessment for the DOE and our participation in the nuclear incident response organizations contribute to these activities.

To Proliferation Prevention and Arms Control, see Section 2.2.1.

4.2.2 Support of Arms Reduction Treaties (NN)

Livermore supports U.S. arms reduction treaties and various dismantlement transparency and material disposition agreements, often in a leadership role. We are developing methods for monitoring warhead dismantlement and for verifying the weapons-related origin of the nuclear materials. Livermore chairs the working group that is evaluating warhead radiation signatures for tracking warheads through the dismantlement process. We also have the technical leadership role in negotiations for the mutual reciprocal inspections of fissile material removed from dismantled weapons. We are working with our Russian counterparts to develop instrumentation for measuring radiation signatures to confirm or deny the weapons origin of inspected nuclear materials without revealing sensitive information. We contribute to discussions related to the U.S. position for future arms reduction agreements limiting warheads.

We also have a principal role in the Fissile Materials Disposition Program, a DOE-led interagency task force that is studying, in partnership with Russian counterparts, various options for disposing of excess weapons-grade fissile materials, specifically plutonium. Two plutonium disposition options are being considered: burning in nuclear reactors (the Russian preferred option) and immobilization in glass or ceramic (the U.S. preferred option). We are developing the technology and processes for immobilizing plutonium in a ceramic waste form for permanent disposition in a geologic repository.

To Proliferation Prevention and Arms Control, see Section 2.2.1.

4.2.3 Counterterrorism (NN)

Livermore's scientific and technical programs provide basic science and new technical concepts to support the nation's response capability for incidents involving weapons of mass destruction (WMD). We are addressing major national initiatives to counter WMD terrorism—specifically, Presidential Decision Directives 39 (1995) and 62 (1998) and the Nunn–Lugar–Domenici legislation (H.R. 3730, 1996).

We are a key player in DOE's Chemical and Biological Weapons Nonproliferation Program. Expertise in analytical methods and instrumentation resident in the Forensic Science Center serves as a basis for our work to counter chemical weapons. Livermore has become a central player in the federal biowarfare response community through new programs in biodetectors, genetic information, transport and fate, and decontamination. We are pursuing two approaches to biodetection—immunofluorescence-based methods using flow cytometry and nuclear acid identification using the polymerase chain reaction (PCR). We have tested these instruments with notable success against standardized performance criteria at the 1996 and 1997 Joint Field Trials, held at the Dugway Proving Grounds in Utah, clearly demonstrating the feasibility of both techniques for field detection of biological agents.

We have launched a new initiative directed at civilian, urban counterterrorism needs. Urban first responders and local emergency managers play a critical role in countering and mitigating acts of WMD terrorism in the U.S. We are working initially with the emergency planning organizations in Los Angeles County and New York City, We have participated in a major exercise in each city and are now a regular member of the Los Angeles emergency planning group. We are working with Los Alamos to understand the gaps in urban first-responder WMD capabilities and to identify capabilities within the national laboratories that could help in urban WMD emergency response. Even in the early stages of this initiative, it is apparent that technologies resident at the national laboratories can be quickly applied to counterterrorism problems in an urban environment.

To Counterterrorism and Incident Response, see Section 2.2.3.

4.2.4 Critical Infrastructure Protection (NN)

Presidential Decision Directive 63 was issued in response to the report by the President's Commission on Critical Infrastructure Protection. PDD 63 recognizes the interconnectedness of the nation's critical infrastructures (energy, water, transportation, finance, etc.) and the need for critical functions to continue in the event of a physical or cyber attack by terrorists. The DOE's obligations under PDD 63 include protection of its own infrastructure and complex, protection of the U.S. energy infrastructure (particularly the electric power grid), and research and development to provide cost-effective protection and rapid reconstitution of critical infrastructures in the event of an attack.

We are marshaling Livermore strengths to assist the DOE in meeting its responsibilities in this vital area. Applicable Laboratory capabilities include the ARGUS system for enhanced physical security, the Computer Incident Advisory Center (CIAC) for cyber protection, and a fundamental core competency in complex systems analysis. A new information operations project is providing valuable tools for identifying vulnerabilities in and protections for Livermore and DOE information networks.

To Critical Infrastructure Protection, see Section 2.3.2.

4.2.5 Sensitive Compartmented Information Facility (IN)

A new Sensitive Compartmented Information Facility (SCIF) building will provide a modern facility for all-source technical analysis. It will also reduce maintenance and special security costs and consolidate Livermore's national security programs in one area of the Laboratory site, enhancing our ability to execute those projects. The Building 261 SCIF, constructed 38 years ago, cannot accommodate all of the people, necessary communications, and computer hardware (information management, networking, data storage and retrieval, and real-time secure communications with DOE and the U.S. intelligence community) that now are required to be in a secure facility. In addition, the current SCIF needs major repairs, is outside the core security area, and thus is no longer cost- or mission-effective to maintain.

The new SCIF building will be located just north of B132 North and west of parking lot A-4. It will use the B170 building plans with slight modifications necessary to accommodate the SCIF and the required contiguous Q-clearance space. The new SCIF will house approximately 125 people in some 115 offices, a graphic illustrators' room, photo lab, print shop, document work areas, and computer rooms. The SCIF will also contain four conference rooms, a library area, a workroom for team projects, classified disposal rooms, and six special access program (SAP) rooms with additional security. The Q space will house about 50 people and consist of about 45 offices, secretarial areas, conference room, and work room.

Estimated cost for the new SCIF building is $24 million. This estimate was confirmed upon completion of a Conceptual Design Report and project validation in May 1999.

To International Assessments, see Section 2.2.4.

4.2.6 Environmental Security Initiative (NN)

Environmental issues, like water resources, pollution, and earthquake mitigation, can significantly affect regional security. Fortunately, many of these issues are amenable to technical mitigation and can thereby serve as vehicles for regional cooperation. The DOE and its national laboratories have formulated a regional Environmental Security Initiative to address these issues in four regions of national security interest to the U.S.

In May 1998, a conference involving many of the Arab states of the Middle East, North Africa, and Eastern Europe was held in Amman, Jordan, to discuss seismic monitoring and earthquake simulation technology to plan monitoring, mitigation, preparation, and emergency response to earthquakes in those regions. A follow-on conference involving a different set of Arab states in further discussions on seismic monitoring was held in October 1998 in Turkey.

Livermore was the catalyst for a collaboration between Jordan, Israel, and the Palestinian Authority to develop water-management strategies for the aquifers and surface water resources in the region. (This work is conducted under the aegis of the DOE, Environmental Protection Agency (EPA), and USAID, with participation from Sandia, Los Alamos, and the National Renewable Energy Laboratory.) In another Livermore-facilitated collaboration (under the aegis of UNESCO), seismologists from many of the Arab states of the Middle East, North Africa, and Eastern Europe are studying seismic monitoring and earthquake simulation technology to plan monitoring, mitigation, preparation, and emergency response to earthquakes in this seismically active region. Livermore capabilities of particular relevance to these efforts include modeling of precipitation, surface and subsurface flow, and the hydrology of aquifer environments as well as seismic monitoring technologies and modeling of seismically induced ground motion and ground–structure coupling. Other capabilities that could be important for environmental security in the region include renewable and fossil energy technology, technologies for purifying sewage for reuse as drinking water or for irrigation or aquifer recharge, contamination prevention, and environmental remediation.

A similar conference focusing on China was held in early 1999 to initiate plans to protect China's water resources from pollution resulting from its burgeoning industrial, urban, and agricultural activities. This work was led by the U.S. Office of Science and Technology Policy; the national laboratory effort is led by Los Alamos and involves Livermore and Sandia.

Talks are continuing among the U.S., Russia, and the Scandinavian countries to identify ways of disposing of spent fuel and nuclear waste from decommissioned submarines to avoid further contamination of the Arctic north of Russia. These plans are needed to enable further decommissioning of Russian submarines. Past Russian disposal practices have caused radioactive contamination of Arctic waters, which in turn threatens fish and other ocean resources in that region. Impact studies and mitigation responses are needed to solve this problem.

See Table 4-6 for resource requirements.

To Proliferation Prevention and Arms Control, see Section 2.2.1.

4.2.7 Chemical and Biological Nonproliferation Program (NN)

In recent years, incidents both abroad and within the U.S. have caused an increased national-level focus on chemical and biological

Table 4-6. Resources required at Livermore to support the Environmental Security Initiative ($M).

Fiscal year	Operating costs	Capital equipment	Total costs	Direct FTEs
1999	0.3	0.0	0.3	1.0
2000	0.5	0.1	0.6	2.0
2001	1.0	0.1	1.1	4.0
2002	2.0	0.2	2.2	7.0
2003	2.5	0.2	2.7	8.0
2004	3.0	0.2	3.2	10.0

nonproliferation. Within this framework, we have begun work that will provide sound molecular data upon which tools can be developed to analyze and synthesize molecular information regarding potential biowarfare agents.

Livermore is currently expanding its efforts in the area of biological nonproliferation and has developed a strong collaborative relationship with colleagues at Los Alamos and Sandia national laboratories. A five-year plan has been jointly proposed and, if funded, will provide major support for the Biological Foundations branch of the Department of Energy's Chemical and Biological Nonproliferation Program. This plan includes support for development of DNA signatures for an expanding list of pathogens, validation of these signatures, background microbial and chemical surveys, structural analysis of toxins, and complete DNA sequencing of several microbial genomes. In addition, this program will support informatics tool development, development of data repositories, online access to data interpretation tools, and web-based tools for crisis managers.

To Proliferation Prevention and Arms Control, see Section 2.2.1.

4.3 Office of Science

4.3.1 Accelerated Climate Prediction Initiative (KP)

Climate, weather, and atmospheric dispersion predictions have long been constrained by computing capabilities in both hardware and software. Under the DOE's Accelerated Strategic Computing Initiative (ASCI), computing capabilities are improving at an unprecedented rate. DOE's Strategic Simulation Initiative, including the ACPI, intends to use this emerging capability for critical national needs beyond defense, thereby broadly improving the national scientific computing capability. The goals of the Accelerated Climate Prediction Initiative (ACPI) are to accelerate and extend the state of the art in climate modeling, to decrease the uncertainties in multi-decadal climate change predictions on global and regional scales, and to make these assessments and predictions accessible to a much broader research community.

A key participant in ASCI, Livermore has extensive experience in atmospheric modeling on global scales with its Program for Climate Model Diagnosis and Intercomparison (PCMDI) and on local scales with the National Atmospheric Release Advisory Center (NARAC). Through a recent collaboration with the Naval Research Laboratory at Monterey, California, we have jointly developed a multiprocessor version of their regional weather prediction model, thus providing us significant modeling capability at all levels: global, regional, and local or urban.

Because of our modeling capabilities, Livermore has provided quantitative support for national assessments of potential climate change and estimates of the impacts of international environmental agreements. As a consequence, a Livermore scientist was recently recognized nationally for his key contributions to the Intergovernmental Panel on Climate Change. More generally, we have worked to enhance the scientific basis for effective, economically viable, environmental national policy. These analytic efforts call for much more sophisticated and accurate modeling tools, as well as greater standardization of coding methods and data structures to facilitate access and comparison. What is ultimately required is a process-comprehensive, scale-coupled, data-corroborated atmosphere–ocean modeling capability.

We are planning and initiating (as resources allow) significant improvements in the resolution, physics, and chemistry of our collaborators' current models and in coupling calculations of nested scales to improve prediction resolution and regional specificity. Needed physics improvements include improved modeling of the hydrological cycle and cloud–radiation interactions (including cloud formation) and better treatment of

Table 4-7. Resources required at Livermore to support the Accelerated Climate Prediction Initiative ($M); the first column represents ongoing programs in global change research, such as PCMDI and others, while other columns include the implementation of ACPI.

Fiscal year	Operating costs	ACPI operating	ACPI capital	Total costs	Direct FTEs
1999	7.5	0.0	0.0	7.5	1.0
2000	6.0	1.5	1.0	8.0	4.0
2001	6.5	3.0	2.5	11.5	8.0
2002	7.0	4.5	3.0	14.5	12.0
2003	7.0	4.5	3.0	14.5	12.0
2004	7.0	4.5	3.0	14.5	12.0

aerosols and reactive (non-CO_2) greenhouse gases. In coupling the oceans and atmosphere, improvement is needed particularly in subgrid-scale (unresolved) processes, such as local air–sea material and energy exchange and mixing and sea-ice thermodynamics. Through ocean biochemical and terrestrial ecosystem processes, changes in the global and regional environments are most readily manifested. These changes are both the best diagnostics and the most important effects of global climate changes. Eventually our models must couple all of these processes at all of the relevant scales—a daunting challenge.

These modeling efforts will necessarily be cooperative ones among a wide number of government, laboratory, university, and private modeling efforts. We have established working arrangements with the PCMDI community of laboratories and universities, and we have initiated modeling collaborations with the National Center for Atmospheric Research, the National Oceanographic and Atmospheric Agency, the National Aeronautics and Space Administration, and the Naval Research Laboratory.

We propose to increase our involvement in enhancing and expanding the science base for atmosphere and ocean model assessment and prediction and to assist in developing the infrastructure for modeling standards, databases, archives, and networks. The resources needed for this are given in Table 4-7.

To Environmentally Sound Energy Technologies, see Section 3.1.2.

4.3.2 Spheromak Fusion Reactor (AT)

Energy production from fusion is the long-standing goal of worldwide fusion research. Although much of this research has focused on the tokamak, the U.S. is now restructuring its national program toward concept improvement, including both improvements to the tokamak and to alternatives to the tokamak concept.

At Livermore, we are undertaking a detailed examination of one of those concepts, the spheromak, which offers the promise of confinement in a simple and compact magnetic field system. In the spheromak, the primary magnetic fields used for energy confinement are generated by a magnetic dynamo, whereas the primary field in the tokamak is generated by external coils. Consequently, relative to the tokamak, the spheromak offers the opportunity for considerable engineering simplicity and lower cost.

The Sustained Spheromak Physics Experiment (SSPX) began operating routinely in April 1999. The physics and experimental efforts are funded by the Laboratory's LDRD Program, and operations are funded by the DOE Office of Fusion Energy Sciences. The overall goal is to understand and optimize energy confinement in the spheromak.

SSPX will demonstrate progress toward an advanced experiment with three major milestones:

- Establishing a sustained plasma, with good control of the magnetic geometry and impurities.
- Evaluating the relationship between energy confinement and the magnetic fluctuations associated with the dynamo and achieving temperatures of a few hundred electronvolts during sustainment.
- Learning how to transfer the equilibrium to external fields (poloidal field coils) and exploring feedback or other control of the tilt and shift modes.

If the results from SSPX are sufficiently promising, our goal is to develop a larger, follow-up experiment, which would include achieving plasma temperatures in the range of multiple kiloelectronvolts, controlling low mode-number instabilities (perhaps with a feedback system), and developing the technology of long-pulse current drives. See Table 4-8 for resource requirements to continue spheromak research.

To Environmentally Sound Energy Technologies, see Section 3.1.2.

4.3.3 Joint Genome Institute (KP)

In recent years, the goals of Livermore's Human Genome Center have undergone a dramatic evolution. This change is the result of several factors both intrinsic and extrinsic to the Human Genome Initiative. They include: (1) the successful completion of the first phase of the project, namely a high-resolution, sequence-ready map of

Table 4-8. Resources required for Spheromak Fusion Reactor ($M).

Fiscal year	Operating costs	Capital equipment	Total costs	Direct FTEs
1999	2.8	0.0	2.8	8
2000	2.4	0.0	2.4	8
2001	2.8	0.0	2.8	8
2002	4.0	0.0	4.0	11
2003	4.0	0.0	4.0	11
2004	10.0	0.0	10.0	30

human chromosome 19; (2) advances in DNA sequencing that allowed us to accelerate scaling this operation; and most significantly (3) the 1997 formation of a Joint Genome Institute (JGI) for the Department of Energy. The JGI includes the three genome centers at the Livermore, Berkeley, and Los Alamos national laboratories.

In the last year, the primary emphasis of our Livermore Center activities has been on establishing the scientific goals, organizational responsibilities, and management structures for the JGI. The Livermore team has taken the lead in developing shotgun sequencing methodology, sequence quality standards, and informatics infrastructure. Construction was completed on the first of two buildings at the JGI Production Sequencing Facility in Walnut Creek, and we have completed the first phase of the move to that facility, with over 40 employees working at that location.

In April 1999, the DOE funded the JGI to sequence five microbial organisms of interest to the DOE community for their energy and bio-remediation programs. This work will be carried out at Livermore for the JGI.

Looking further ahead, we plan to move our focus back to the functional aspects of genomic research. This work has been temporarily scaled back to allow us to concentrate on establishing the high-throughput sequencing capability for the JGI. For the long term, we believe that extracting biologically relevant information from sequence data should be a focus of work at Livermore, including comparative sequencing, particularly of regions of the mouse genome, cDNA characterization, protein characterization, computational data mining, and understanding the relevance of human polymorphisms. Continuing resources needed to carry forward this initiative are shown in Table 4-9.

To Genomics, see Section 3.2.1.

4.3.4 Disease Susceptibility: Functional and Structural Genomics (KP)

With funding from several sources, we have initiated a program in disease susceptibility that combines our genomics capabilities with new capabilities in functional and structural biology to bring a scientific basis to disease risk assessment. This program is relevant to DOE's growing interest in linking products of the Human Genome Project and its biosciences capabilities to disease susceptibility and to increasing national interest in identifying how genetic defects alter molecular structure and cause cancer and genetic disease. We have established and will make use of a state-of-the-art cryocrystallography and x-ray diffraction facility, a 600-megahertz nuclear-magnetic-resonance facility, computational biochemistry, mouse genomics, microbial genomics, and a protein-structure prediction center.

In FY 1997, DOE provided funding to initiate study of the sequence variation in human DNA repair genes and to support the protein structure prediction center, in which we have been advancing methods of identifying protein structure from its DNA sequence. Additional funds are needed to support DNA sequencing of susceptibility genes during the period when the Joint Genome Institute is generating human DNA sequence in a production mode and to extend the genetic variation studies beyond the current pilot phase. Funds are also needed to maintain the core Livermore capabilities in x-ray diffraction and for three-dimensional structure analysis of DNA repair proteins, nucleic acids, and the complexes they form with one another and with other molecules. GPP funding is needed to renovate our existing animal facility for mouse genomics. This program will produce insights and tools to predict the structure (and possibly the function) of proteins from DNA sequences, a critical capability when DNA sequences are becoming available from the Human Genome Project at a rapidly accelerating rate. Table 4-10 shows resource requirements for this initiative.

To Disease Susceptibility, see Section 3.2.3.

4.3.5 Computational Biochemistry (KP)

The Biology and Biotechnology Research Program (BBRP), in collaboration with the Computation and Physics Directorates, has initiated development of an integrated computational chemistry capability. Our goal is to increase the impact of computational chemical modeling in ongoing programs and seed new programs. The Laboratory's new teraops computing capacity will allow highly realistic simulations, including multihundred-atom quantum-chemistry and microsecond molecular-dynamics calculations. These powerful new modeling capabilities will have applications in numerous Livermore programs, including the study of normal and chemically modified DNA to support the BBRP's DNA repair and disease susceptibility research and the Laboratory-wide applications in studies of corrosion and aging and in designing new materials.

Accomplishing these goals requires a multidisciplinary approach. Chemical modeling algorithms and software must be developed and validated, an effort primarily of computational chemists. Computer scientists with expertise in networking and software development must develop transparent interfaces between desktop computing resources and supercomputers. Education and guidance in using these new resources must be ongoing to ensure the maximum synergy between end users with varying research needs and the team responsible for continuing development.

This effort, started in FY 1997 with support of the Laboratory Directed Research and Development Program, requires additional and sustained funding to maximize its impact on biotechnology. Tables 4-11 shows resources required for the initiative.

To Disease Susceptibility, see Section 3.2.3.

4.3.6 Microbial Genomics (KP)

To study organisms of interest to those working in health effects, environmental remediation, and biological nonproliferation, we would like to continue to broaden our genomics program, using the technologies developed for the human genome project. An expanded program in microbial genomics would lead to a variety of potential health benefits. We recently began a program in the genomics of microbial pathogens, focusing on virulence factors with both sequencing and hybridization-based methods. Similar technologies could be applied to organisms of interest for environmental studies and bioremediation. Table 4-12 gives the resource requirements for this effort.

To Biological Nonproliferation, see Section 3.2.2.

4.3.7 Pilot Projects in Biomedical Engineering (KP)

In 1999, DOE announced a new initiative designed to support research at the national laboratories that will make significant contributions to improving human health. Focal areas include biomaterials, biomedical applications of lasers, imaging, and informatics, and

Table 4-9. Resources required for LLNL Joint Genome Center (BA in millions of FY2000 dollars after FY 1999).

Fiscal year	Operating costs	Capital equipment	Total costs	Direct FTEs
1999	25.2	2.0	27.2	101
2000	30.1	2.0	32.1	120
2001	32.0	2.0	34.0	130
2002	34.0	2.0	36.0	140
2003	36.0	2.0	38.0	145
2004	38.0	2.0	40.0	150

Table 4-10. Resources required for Disease Susceptibility: Functional and Structural Genomics Initiative (BA in millions of FY 2000 dollars after FY 1999).

Fiscal year	Operating costs	Capital equipment	Total costs	Direct FTEs
1999	13.7	0.8	14.5	68
2000	14.2	0.5	14.7	71
2001	14.7	0.5	15.2	73
2002	15.2	0.5	15.7	76
2003	15.7	0.5	16.2	78
2004	16.2	0.5	16.7	80

Table 4-11. Resources required for Computational Biochemistry (BA in millions of FY 2000 dollars after FY 1999).

Fiscal year	Operating costs	Capital equipment	Total costs	Direct FTEs
1999	1.3	0.0	1.3	7
2000	1.6	0.1	.7	8
2001	1.9	0.1	2.0	10
2002	2.1	0.1	2.2	11
2003	2.3	0.1	2.4	12
2004	2.5	0.1	2.6	13

Table 4-12. Resources required for Microbial Genomics (BA in millions of FY 2000 dollars after FY 1999).

Fiscal year	Operating costs	Capital equipment	Total costs	Direct FTEs
1999	3.2	0.1	3.3	13
2000	4.0	0.2	4.2	16
2001	5.0	0.2	5.2	20
2002	6.0	0.2	6.2	24
2003	7.0	0.2	7.2	28
2004	8.0	0.2	8.2	32

biological, chemical, and genetic sensors. We are uniquely poised to make contributions in many of these areas. Projects exist in every directorate across the Laboratory. The Laboratory's Council on Biosciences and Biotechnology coordinates this cross-laboratory effort.

Funding for these projects comes from diverse sources, including DOE, the Laboratory Directed Research and Development Program, and industrial funding. Currently, we are working with both the DOE and the National Institutes of Health to increase funding from these sources. We expect biomedical engineering to be a growth area for the Laboratory over the next several years.

To Health Care and Medical Biotechnology, see Section 3.2.4.

4.3.8 Materials Studies and Surface Characterization (KC)

Livermore is developing a suite of experimental capabilities to improve the ability to characterize and study materials and surfaces. These new capabilities will permit unparalleled experimental accuracy in investigations of defects, voids, surface contaminants, and the impact of aging, stress, and impurities on the microscopic behavior of materials. These capabilities offer opportunities for breakthroughs in materials research—of interest to the Office of Basic Energy Sciences in the DOE Office of Science—and for detailed examination and characterization of materials in aging nuclear weapons—of interest to DOE Defense Programs. The new and developing initiatives include:

- **The LLNL Positron Facility.** Livermore is developing a unique and powerful set of technologies using positrons to study defects and voids in materials. The presence of such defects—even at the atomic level—represents the dominant factor controlling changes of the mechanical and electrical properties of technological materials such as metals, semiconductors, and insulators. The unique capabilities of the Positron Facility, which enables advances in our understanding of material defects and the phenomena that produce them, have attracted the interest of the entire materials community, including scientists at Los Alamos and other national laboratories, researchers from a broad academic community, and various industrial concerns. Scientists have begun moving unique instrumentation to Livermore to conduct materials research with positron beams. Probing vacancy-type defects at the atomic scale to determine their size and concentration requires an innovative approach—positron spectroscopy. The sensitivity of this technique extends to smaller defect sizes and lower concentrations than reachable by any other method. Leveraging the capabilities at Livermore's 100-MeV LINAC, we are developing a truly unique instrument—the positron microprobe—which will provide an unrivaled defect analysis capability to model three-dimensional maps of buried defects with submicron spatial resolution.
- **Surface Characterization with Highly Charged Ions.** Using the Electron Beam Ion Trap (EBIT) facility at Livermore, we are developing a technique to obtain extremely detailed information about a surface and its contaminants. When a highly charged ion produced in the EBIT approaches a surface, the enormous potential energy causes the surface to emit hundreds of electrons. For many materials, this loss of electrons from a nanometer-scale area of the surface results in a large local excess of positive charge, which, in turn, leads to a highly localized breakup or sputtering of the surface that can be studied in great detail. The use of EBIT for surface characterization is of interest to both DOE Defense Programs and Office of Science, and the approach presents innovative research opportunities for many university-based research programs. In addition to materials research, the potential of the technique to modify surfaces at the nanometer scale is being examined by scientists for a variety of industrial and national security applications.

To Application of Mission-Directed Science and Technology, Section 3.3.2.

4.4 Assistant Secretary for Energy Efficiency

4.4.1 Fuels Assessment (EE)

Transportation fuels are a crucial component of the economic infrastructure of the U.S. However, they pose a variety of health and environmental risks. Historically, regulatory agencies, as well as the auto and oil industries, have had difficulties in predicting and managing those risks. For example, the health and environmental impacts associated with the use of tetra ethyl lead and, recently, methyl tertiary butyl ether, were never properly assessed before their introduction to the market. Part of the problem is that such assessments are inherently complex and multidisciplinary and cannot be completed in any coherent fashion by multiple organizations with different missions.

A collaborative effort between Lawrence Livermore and Sandia national laboratories and the University of California can provide the needed expertise to create and implement methodologies for science-based analyses of fuels and fuel additives. To formalize this collaboration, we are establishing a consortium for fuels assessment, whose charter will be to conduct strategic health and environmental evaluations of the nation's fuels for the 21st century. Although the scientific and policy expertise found at the Laboratory and collaborating institutions constitutes the foundation for the work, the collaboration's success will depend on strong links to the oil and automotive industries.

Livermore is uniquely qualified to lead this effort because we have the technical capabilities to assess the health and environmental consequences of the entire lifecycle of a given fuel or additive—its production, distribution, storage, and use. Research on each lifecycle element will address three fundamental topics:

- Quantification of contaminant releases to air, surface water, groundwater, and soil.
- Characterization of the transport and transformation of fuel-related substances in environmental media.
- Assessment of the potential health and ecological risks of those substances.

Our expertise in these assessment topics includes both state-of-the-art computer models and experimental methods. For example, Livermore has developed sophisticated chemical kinetic models for simulating combustion products from an engine, while Sandia has a laboratory devoted to measuring emissions produced by combustion of different fuels. An important resource is our extensive suite of models for simulating the transport of fuel-related contaminants in air, soil, surface water, and groundwater. Our analytical capabilities for measuring contaminants in various sample matrices range from standard chromatographic techniques to the world-class Center for Accelerator Mass Spectrometry. Risk-assessment capabilities include models and experimental techniques for quantifying inhalation, ingestion, and dermal exposures to contaminants, as well as the internal doses and associated risks.

The key to establishing a successful consortium will be to implement assessment methodologies that take full advantage of our capabilities and result in scientifically sound assessments of the risks posed by fuel compounds. We are directing our current efforts toward defining integrated assessment methodologies and establishing collaborations with industry, government agencies and laboratories, and the University of California campuses to set the stage for interactions with potential sponsors. Our goal is to secure the funding within the next year and begin studies that will help the nation determine the best fuels for the next century.

The primary funding source will be the Assistant Secretary for Energy Efficiency supplemented by funds from the Office of Fossil Energy and the U.S. Environmental Protection Agency. Table 4-13 shows the resources required for this effort.

To Environmentally Sound Energy Technologies, see Section 3.1.2.

4.4.2 Hydrogen as an Alternative Fuel (AR)

Alternative fuels that are clean, efficient, and potentially carbonless and that lessen U.S. dependence on foreign energy supplies are critical to ensuring U.S energy security and sustainability. Hydrogen is a strong near-term contender as an alternative fuel because it satisfies these strategic criteria and can be made from a variety of domestic sources using existing infrastructures.

In the longer term, when renewable electric power sources, such as wind and solar thermal and photovoltaic power, become major suppliers to the national energy grid, hydrogen will provide both transportation fuel and the "energy intermediation" needed when demand peaks exceed primary grid supplies. Hydrogen will then be produced by utilities for centralized fuel distributions and some recycling to electricity and by local electrolysis at service stations and homes for distributed transportation needs. We

Table 4-13. Resources required for Fuels Assessment ($M).

Fiscal year	Operating costs	Capital equipment	Total costs	Direct FTEs
1999	0.5	0.0	0.5	2.5
2000	2.0	0.0	2.0	10
2001	3.0	0.0	3.0	15
2002	3.0	0.0	3.0	14
2003	3.0	0.0	3.0	14
2004	3.0	0.0	3.0	14

propose several initiatives that can positively impact the feasibility of hydrogen fuel.

We have developed and tested an economic equilibrium model that can optimize the cost structure for future electric utility and transportation sector configurations. For the long-term, we propose to identify the most cost-effective integration of carbonless electric and transportation sectors. We propose to use this model to determine the critical technology performance criteria, compare technology options, and plan transition strategies.

Two technologies—critical for transitions now and in scenarios of the future—are light, compact onboard fuel storage for cars and trucks and efficient, scalable steam electrolysis. We have proposed and begun development of a cryogenic-capable pressure tank that can efficiently store pressurized hydrogen gas for short range and at-home refueling and liquid hydrogen for long-range and station refueling. We estimate a vehicle range as great as 800 miles for the Partnership for the Next Generation of Vehicles' performance vehicles. We propose to engineer, performance test, and safety test this storage mode for inclusion in a vehicle demonstration.

Steam electrolysis with a solid-oxide electrolyte can achieve hydrogen production efficiency greater than 100% if auxiliary heat is available from other process sources. The hydrogen can be produced either from a pure water (steam) feed stock or from steam and methane, which might require carbon sequestration, but which has strong electrochemical efficiency advantages that might compensate for the additional processing. We propose a three-year program to develop and demonstrate a 10-kilowatt solid–oxide electrolyzer, which would be adequate to provide fuel for a single vehicle. This same technology is applicable to the development of efficient, solid–oxide fuel cells.

Remote power applications offer immediate opportunities to demonstrate the technical feasibility of hydrogen technology systems because of the high cost of off-grid power. We are studying use of hydrogen for remote power applications in Nevada, Alaska, Pike's Peak National Monument in Colorado, the Philippines, and southern Italy.

We would like to provide energy system options that can influence national transportation and utility decisions within the next decade and be economically significant within two decades. See Table 4-14 for resource requirements for this effort. In addition to this DOE support, we will continue to develop industrial partnerships.

Table 4-14. Resources required for Hydrogen as an Alternative Fuel ($M).

Fiscal year	Operating costs	Capital equipment	Total costs	Direct FTEs
1999	2.0	0.3	2.3	7
2000	2.0	0.4	2.4	7
2001	4.5	0.4	4.9	16
2002	4.0	0.3	4.3	13
2003	4.0	0.2	4.2	12
2004	4.0	0.2	4.2	12

To Environmentally Sound Energy Technologies, see Section 3.1.2.

4.5 Multiple Program Offices

4.5.1 Nuclear Materials Initiative (Multiple Program Offices)

DOE is responsible for a wide variety of nuclear materials and operations that are used to fuel civilian power reactors and research reactors (domestically and in other countries), to produce defense-related materials, and to power naval vessels. DOE controls an extremely complex and dynamic inventory of resources, facilities, and operations with which nuclear materials are created, processed, used, stored, and prepared for disposal. These activities are governed by numerous laws and regulations, by DOE responsibilities to state and other federal agencies, by U.S. cooperation with international organizations, and by U.S. treaty obligations.

In this context, Livermore serves as a national technical resource in enhancing safe, secure, economic, and environmentally sound conduct of nuclear operations. Although other DOE laboratories have large research efforts under way in either nuclear energy or nuclear weapons, Livermore is unique in the breadth and scale of aggregate nuclear activities, from nuclear weapon materials to the nuclear fuel cycle, nuclear systems safety, and public health. We now perform more than $300 million of nonweapon, nuclear-materials-related research per year as outgrowths of our science and technology base and of our experience with nuclear systems in support of national security.

Our intention is to coordinate these activities and use our aggregate capabilities to create a broadly applicable national resource for the management of nuclear materials. Emerging strategic issues that are likely to help shape DOE missions and U.S. nuclear materials agendas over the next 5 to 10 years include:

- Excess special nuclear material from weapons, generated by the reduction of nuclear arsenals in the U.S. and Russia. These materials require a disposition path that is both technically feasible and politically acceptable.
- The post–Cold War environmental legacy. Environmental cleanup and waste management needs of the defense complex continue to have a major impact on DOE budgets, credibility, operations, and missions.
- Management and disposal of civilian spent nuclear fuel. DOE is facing significant deadlines regarding spent fuel acceptance and the Yucca Mountain repository site viability. Because Yucca Mountain is currently the expected disposition endpoint for many defense-related, high-level nuclear waste materials, the impact of Yucca Mountain decisions and activities will be felt in other parts of the defense complex.
- Growing demands for nuclear power (particularly in Asia). The U.S. faces significant competition in the nuclear technology marketplace. Nuclear fuel reprocessing is continuing globally despite U.S. efforts to discourage this practice.

Drawing upon our resources that are spread across several directorates and disciplines, we will support DOE's efforts to resolve these strategic issues and will focus on new mission-oriented work, especially in support of high-level waste, plutonium stabilization and disposition, mixed oxides (MOX), and greater-than-Class-C wastes. We will work with other laboratories and DOE Program Offices to respond to initiatives being developed by the Secretary's Office and the Albuquerque Operations Office. See Table 4-15 for resource requirements to continue this effort.

To Nuclear Materials Management, see Section 3.1.1.

4.5.2 Accelerator Technologies (Multiple Program Offices)

Livermore contributes to national accelerator R&D programs with its innovative approaches to accelerator design and detector systems and its broadly based capabilities engineering, precision manufacturing, and multidisciplinary project management. We were part of the three-laboratory effort to build the B-Factory at Stanford, and our accelerator expertise is being applied to important national security applications, including the development of advanced technologies for hydrodynamic test radiography. One of the major technology candidates is the use of high-energy protons as the radiographic probe. We have been working on the design of a machine and detectors for proton radiography. This design effort has been carried out in collaboration with the DOE's High Energy Physics Program at several DOE national laboratories (Brookhaven National Laboratory, Fermi National Accelerator Laboratory, and Stanford Linear Accelerator Center). Important technology demonstration experiments are being conducted or are planned.

In addition, Livermore is partnering with Los Alamos, several other national laboratories, and industry to investigate the use of high-power proton accelerators to transmute radioactive waste into more manageable forms. Transmutation of waste is being studied as a technology that can contribute to the disposition some 70,000 tons of radioactive wastes from the nuclear power industry. A five-year R&D program is envisaged to optimize the techniques, investigate options within the program, conduct the appropriate system studies, and understand the impact on the overall problem facing the nation.

We can also make important contributions to major user facilities being planned by the DOE Office of Science:

- **The Next Generation Light Source.** Advances in low-emittance electron linacs over the past several years have opened up the possibility of a fundamentally new kind of synchrotron light source of unprecedented brightness. A free-electron laser (FEL) consisting of such a linac driving a long precision-

Table 4-15. Resources required for Nuclear Materials Initiative ($M).

Fiscal year	Operating costs	Capital equipment	Total costs	Direct FTEs
1999	5.0	0.0	5.0	7
2000	5.0	0.0	5.0	10
2001	10.0	0.0	10.0	20
2002	10.0	0.0	10.0	20
2003	10.0	0.0	10.0	20
2004	10.0	0.0	10.0	20

fabricated undulator can produce monochromatic 1-angstrom radiation 10 billion times brighter than existing "third-generation" facilities such as the Argonne Advanced Photon Source. The recent review of the national synchrotron facilities by a Basic Energy Sciences Advisory Committee (BESAC) subpanel gave its highest recommendation to a vigorous R&D program on "fourth-generation" light sources. Livermore is a charter member of a consortium including SLAC, LANL, and UCLA that is carrying out R&D toward a demonstration facility, called the Linac Coherent Light Source (LCLS). LCLS is a $100-million project that would begin construction in FY 2003. Livermore is involved in several key aspects of the project, including undulator design, low-emittance electron sources, and novel x-ray optics.

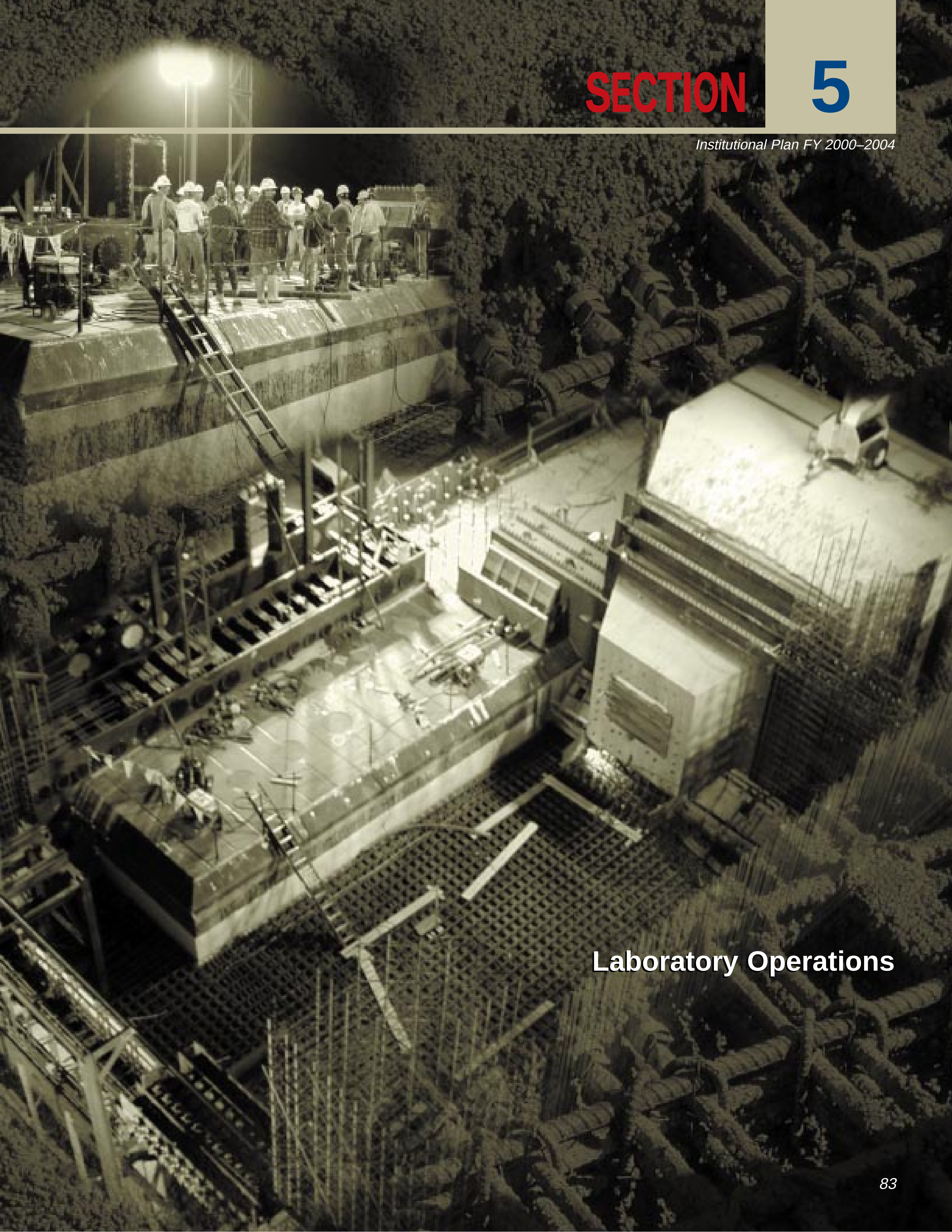
- **The Next Linear Collider.** The next major high-energy physics machine in the world after the CERN Large Hadron Collider will likely be a teraelectronvolt electron–positron linear collider. This Next Linear Collider (NLC) would be a 30-kilometer-long facility, costing several billion dollars, with the U.S. and Japan as the major players. The scientific thrust of the NLC is a full exploration of physics beyond the Standard Model, including the study of the spectra of Higgs particles and determining whether Supersymmetry is a valid description of nature. The U.S. and Japan have recently entered into an agreement to work on one technical baseline design for the machine. The recently issued High Energy Physics Advisory Panel (HEPAP) subcommittee report strongly recommended DOE to proceed with a Conceptual Design Report (FY 1999 to 2001). The collider is patterned after the very successful B Factory collaboration. Construction would begin in FY 2002 if approved, with commissioning around FY 2008. SLAC, Livermore, and LBNL are the U.S. leaders for this project. The Laboratory has undertaken advanced manufacturing, one of the most challenging roles in the R&D program, namely advanced manufacturing on the 20-kilometer precision accelerator structures, to make large cost reductions in the project. The Laboratory is also applying its unique expertise in high-average-power, short-pulsed lasers toward the design of a second interaction region: a high-luminosity gamma–gamma collider that would open up entirely new physics complementary to the electron–positron collisions.

To Application of Mission-Directed Science and Technology, Section 3.3.1.

4.5.3 Computational Materials Science and Chemistry (Multiple Program Offices)

The Laboratory is committed to continuing the expansion and enhancement of our ability to accurately model and predict the behavior of emerging and aging materials. Materials often must perform in adverse and stressing environments (corrosion, radiation, high temperature, etc.), and we are actively engaged in understanding the impact of such environments. Livermore's research efforts cover a broad spectrum of activities, from molecular design and metal physics to predicting the macroscopic behavior of materials. Much of our effort is focused on the atomistic and molecular regime where *ab initio* calculations of interatomic potentials lead to predictions of atomic structure and molecular stability. We are also developing an understanding of mechanical properties by examining the relationship between defect structures described atomistically and the deformation behavior of individual grains of a metal. Our goal is to develop, in a predictive manner, the macroscopic materials parameters that are essential input to macro-scale simulation codes that are used to characterize the mechanical response of complex materials assemblies to loads. We are also developing models of radiation-induced changes in solids based on an atomistic understanding of the defect structure and its influence on microstructure evolution, as well as methods to model and predict stress-corrosion cracking.

To Application of Mission-Directed Science and Technology, see Section 3.3.1.



SECTION 5

Laboratory Operations

Engineering works with contractors and Livermore scientists in designing, building, and implementing "Xtreme" projects and systems. Here, after construction of the new Contained Firing Facility at Site 300, is where high-explosives tests will again use Livermore-developed tools for stockpile stewardship research. Diagnostic tools will include the double-pulsed Flash X-Ray machine, a linear induction accelerator for diagnosis of hydrodynamics test by radiographing the interior of an imploding high-explosive device, and the multibeam Fabry-Perot interferometer, which provides as many as 20 data collection points for measuring surface velocities during an experiment.

IN all Laboratory operations, we strive to set a standard of excellence in performance, safety, and security among high-technology applied research and development institutions. High-quality, cost-effective operations and supporting infrastructure underpin the success of Livermore's research programs.

The Laboratory's operational services must consider a diverse set of customers—the technical programs, sponsors, Congress, Laboratory employees, and the local community—to name just a few. To best meet the different, sometimes conflicting needs of these customers, the Laboratory operates as an integrated system. Our goal is to have an overall balance of capability and infrastructure that successfully support the Laboratory's objectives. Four overarching strategies reflect Laboratory priorities for operations.

Safety and Security as Top Priorities

Safety and security are the most important considerations in Laboratory operations, and we are taking substantial steps to improve our performance in these areas. Better performance requires the attention and efforts of senior managers at the Laboratory as well as the proper training and vigilance of all employees. Recent events have reinforced the prime importance of security at the nuclear weapons laboratories. Working closely with Secretary Richardson and other senior DOE managers, Livermore, Los Alamos, and Sandia have defined and are expeditiously executing a series of measures to tighten security. At Livermore, we are taking specific actions: providing even greater protection of critical assets at Livermore, implementing state-of-the-art cyber security, and expanding the Laboratory's counterintelligence program. In the area of safety, we are aggressively implementing DOE's Integrated Safety Management System to improve safety performance and management at Livermore.

An Emphasis on Teamwork

Since the founding of the Laboratory by E. O. Lawrence in 1952, team science—the ability to respond to challenges by forming multidisciplinary teams to get the job done—has been one of Livermore's key strengths. Teamwork is a broadly applied principle at the Laboratory—using a matrix management system to focus scientific and engineering talent where needed and integrating operational support with programs to achieve mission success. To seamlessly integrate Laboratory operational support with programs, staff and systems must be flexible, agile, and cost effective, adding value to Livermore's technical work. Many critical aspects of smooth and effective Laboratory operations, such as safety, security, and environmental protection, are every employee's responsibility.

Strategic Institutional Reinvestment

The Laboratory has been implementing a well-defined initiative to streamline business practices, improve information management, and outsource services when practical and cost effective. The result has been about a 30% reduction (inflation adjusted) in traditional General and Administrative (G&A) costs between FY 1993 and FY 1998. These reductions have returned about $50 million to the Laboratory for programs and for meeting strategic institutional reinvestment needs. Reinvestment dollars are currently being allocated to specific objectives directed at strengthening the Laboratory's scientific and technical base, meeting critical infrastructure and facility needs, and realizing long-term cost savings through one-time investments anticipated to have high return-on-investment ratios. Specific areas pertaining to Laboratory Operations, such as facilities maintenance, have been identified as high-priority items for institutional reinvestment.

Use of Performance-Based Management to Improve Operations

In 1992, the University of California (UC) and the Department of Energy pioneered a contracting approach that integrated performance-based requirements into the contract for managing and operating the three UC laboratories. Performance-based management is contributing to improvements in Laboratory operations in several significant ways:

- **Benchmarking to understand norms and improve performance measures**. Across almost the entire spectrum of operational activities, we are benchmarking our performance with that of other research and development laboratories to find ways to better gauge performance and identify specific areas that warrant improvement.
- **Use of performance measures to improve operations.** Through iteration and continual improvement of the self and DOE assessment processes, Livermore has markedly improved operations, as measured by factors such as cost efficiency, service timeliness, and work quality.
- **Performance-based management as a means of building teamwork.** In addition to team building within the Laboratory, Livermore's performance-based management system is fostering a closer working relationship among the Laboratory, the University of California, and the Department of Energy. Through a variety of forums, we are achieving better communication of performance expectations, more efficient oversight, and ultimately, improved performance.

Striving to Meet the Laboratory's Milestones by 2001

Laboratory Activities	Milestones
Section 5 Laboratory Operations 5.1 Environment, Safety, and Health (ES&H) 5.2 Laboratory Security 5.3 Laboratory Personnel 5.4 Facilities and Plant Infrastructure 5.5 Indirect Services 5.6 Information Management 5.7 Internal and External Communications	• The Laboratory has made significant gains in improving safety and is now viewed as a leader in the DOE complex. • Livermore's operational record in counterintelligence and physical security continues to be viewed as excellent, and the Laboratory has made state-of-the-art advances in cyber security. • The workforce and management reflect an ability to attract and retain a high-quality and diverse staff. • The National Ignition Facility building complex is complete, and laser support equipment is being installed. • The Laboratory is increasingly recognized as integral to the state of California.

5.1 Environment, Safety, and Health (ES&H)

Livermore's goals are for Laboratory operations to be conducted in an environmentally responsible manner, for safety to be integrated into programmatic and support activities as a top priority and executed in a cost-effective manner, and for ES&H performance to be comparable to the best of our peers.

We aim to be recognized as an institution capable of carrying out challenging projects and state-of-the-art research and development in a safe manner. To this end, we are implementing DOE's Integrated Safety Management system and expect to meet high standards of ES&H performance within our current operations budgets. Accidents are preventable through close attention to potential hazards and diligence by each individual and responsible organization. It is of paramount importance that employees take responsibility for making the Laboratory a safe place to work and that the community sees us as a good neighbor, concerned about safety as well as health and the environment. To achieve our ES&H goals:

- Our Laboratory culture must place high priority on ES&H as both a line management responsibility and an individual responsibility.
- ES&H must be fully integrated into all Laboratory activities, with appropriate balance between risk acceptance and costs.

Situation and Issues

The Laboratory is known as a safe place to work. Our policy is that safety of both workers and the public has the highest priority. Although we work with hazardous materials and execute complex operations, our activities must be conducted safely, and the public and the environment must be protected. Employees are well trained and empowered to stop work when they are uncertain of the safety of an operation.

In December 1997, DOE completed a Safety Management Evaluation (SME) that reviewed the broad scope of Livermore's ES&H program. The SME used the basic principles of DOE's Integrated Safety Management approach as a guide in evaluating the Laboratory. Overall, the program exhibited many strengths with strong performance in four of the seven ISM principles. These strengths include clearly defined management roles and responsibilities, mechanisms for contractual accountability, an appropriate balance between safety and mission-related priorities, and effective identification of requirements. No deficiencies in need of immediate remedial action were identified; however, we can take steps to improve safety procedures and our safety record. The SME identified three areas for improvement:

- The translation of top-level policies into working-level process and guidance.
- Performance evaluation and feedback.
- Work planning and execution.

Special emphasis was placed on needed improvements in work planning, e.g., hazard identification and analysis and the planning, authorization, and control of work.

Improving Everyday Safety. At Livermore, we have tended to focus our attention on special hazards associated with high-technology research projects. However, we can and must do better at preventing minor accidents connected with day-to-day activities. Most of our accidents and injuries involve strains and sprains associated with routine work and could be reduced by better work planning, greater personal awareness of safety issues, and positive steps to fully integrate safety considerations in all operations. Top management involvement and leadership; clear roles, responsibilities, and performance expectations; and accountability are essential for improving safety performance.

Integrated Safety Management. Senior management is involved in and committed to the success of DOE's Integrated Safety Management (ISM) System that is being implemented at the Laboratory. In pursuing ISM and improved ES&H performance, we will continue to communicate openly with the community on ES&H matters, a move that already has strong support from the local community. For example, several years ago, the Laboratory successfully adopted a practice of providing timely news releases on significant ES&H events to build trust with the community. Community members participate on working groups related to Livermore's Superfund groundwater cleanup and construction of the National Ignition Facility. Ad hoc public hearings are also held, as appropriate, on ES&H issues.

Complying with Environmental Regulations. Livermore's Site Annual Environmental Report, prepared each year by our Environmental Protection Department, summarizes the results of environmental monitoring and provides an assessment of the impact of Laboratory operations on the environment and the public. In addition to our responsibilities to employees and neighboring communities, we must ensure compliance of Laboratory programs with the National Environmental Policy Act (NEPA), the California Environmental Quality Act, and related federal and state requirements. Environmental protection efforts include environmental monitoring, risk assessment, and analysis, as well as major endeavors in environmental restoration—principally groundwater cleanup—and hazardous waste reduction and disposition.

Strategy Thrusts

Implementing ISM. We are proceeding with the implementation of Integrated Safety Management (ISM), including Work Smart Standards (WSS), at all levels of the Laboratory. ISM is now part of our performance-based management system. Through effective involvement of senior management together with line organizations and employees across the Laboratory, we will improve the safety management process, enhance the Laboratory's safety culture, and significantly improve safety performance. As part of this effort, Livermore is selecting a WSS set that will be implemented throughout the Laboratory for the full spectrum of our activities, from R&D to routine maintenance and operations. ISM-defined formality of work processes, which are well-defined procedures to follow depending on the task, will be tailored to match the level of complexity and the risks posed by associated hazards.

Consistent Practices. We are also establishing Laboratory policy guidelines specific to ES&H to enhance accountability. Practices followed at high-performance, private-sector R&D organizations are being studied as a guide. A major focus is on better defining and articulating the flow of responsibility in Livermore's matrix management system. We will also review our system of rewards and discipline for ES&H to assure consistency and to both promote safety and better deal with safety violations and poor safety performance.

Consistency across the Laboratory in ES&H practices is important for achieving cost efficiency while meeting safety goals. Full implementation of ISM during FY 2000 will lead to more uniform practices across the Laboratory yet will allow for local adjustments to meet special circumstances. These measures will ensure clear communication of expected safety practices, effective training, and interchangeability of skills. Clearly defined roles and responsibilities will be formalized through memoranda of agreement between all organizations and facilities. These agreements, which are particularly important issues for the Laboratory's nuclear and other hazard-ranked facilities, will delineate communication protocols, maintenance responsibilities, and reporting requirements.

Work activities are to be formally reviewed and authorized before work begins, consistent with the work planning and authorization process. As a part of the ISM system, existing safety manuals throughout the Laboratory will be updated and organized into a structure consistent with the ISM plan.

Cost Effectively Reducing Waste. Environmental protection efforts will continue to focus on the use and further development of cost-effective technologies and acceptable methods, regardless of origin, for pollution prevention and site cleanup as well as for waste reduction and management. Direct funding for environmental restoration and waste management at the Laboratory is shown in Table 5-1. Because environmental protection begins with pollution prevention and waste minimization, we are taking concerted steps to reduce both the hazardous and nonhazardous waste generated by Laboratory programs. As for waste management, facilities and waste-handling operations are managed to minimize the impact on the environment and to maximize the efficient use of environmental management operating funds. We will strive to continually improve efficiency and reduce waste inventory as we operate Livermore's waste facilities.

Remediation and Restoration. We also will continue activities to better characterize and clean up hazardous materials and contaminated groundwater at the Livermore site and Site 300. In these environmental remediation and restoration efforts, we will develop and test innovative solutions that have broad application to environmental problems at other contaminated sites.

5.2 Laboratory Security

Protection of sensitive information, nuclear materials, and other valuable assets at the Laboratory is a critically important aspect of responsible operations. Effective protection depends on the efforts of the Laboratory's safeguards and security professionals, computer security experts, and counterintelligence specialists as well as the proper training and vigilance of all employees.

We take security very seriously at Livermore. An extensive apparatus is in place at our Laboratory, and we continually make adjustments and upgrades to address new threats and concerns. Protection is provided by employing increasingly sophisticated measures in a cost-efficient manner through a triad of security—physical, cyber (or computer), and counterintelligence.

Physical security, based on a series of defensive layers and access control, is implemented by our Safeguards and Security Program. We take a graded approach to physical security in which physical barriers (e.g., fences, doors, repositories, and vaults) and permitted access are increasingly stringent, depending on the value or sensitivity of the asset.

Cyber security provides protection of the Laboratory's electronic information, computers, data networks, and telecommunications systems in a world that is growing ever more interconnected and dependent on the transfer of digital information. Computer security experts at the Laboratory ensure compliance with DOE orders relating to computer security, coordinate training on computer security issues, and provide capabilities in threat analysis, incident response, and computer security forensics.

Counterintelligence at the Laboratory is the responsibility of the SAFE (Security Awareness for Employees) program. SAFE was formed in January 1986 in response to a Presidential Decision Directive dated November 1, 1985, that required all U.S. government agencies to establish their own counterintelligence programs. SAFE's purpose is to identify and counter foreign intelligence threats against Laboratory personnel, information, and technologies.

Situation and Issues

Security Challenges of Global Science and Technology. A major challenge facing the Laboratory is to protect

Table 5-1. Direct funding for Environmental Restoration and Waste Management Program plans and initiatives, including capital funding ($M).

	FY 1998	FY 1999	FY 2000	FY 2001	FY 2002	FY 2003	FY 2004 and beyond
Waste Minimization and Pollution Prevention	1.1	1.1	0.9	0.9	0.9	0.9	0.9
Environmental Restoration	21.6	22.3	22.3	22.8	22.8	22.8	24.9
Waste Management	30.7	27.5	25.3	25.8	24.5	23.0	22.0

sensitive information and technologies as we participate in an increasingly global scientific and technical community. As a national security laboratory, Livermore must provide a secure environment for sensitive information and special nuclear materials as well as protect valuable government property. At the same time, access by non-Laboratory employees to many of Livermore's facilities is necessary. We work in partnership with universities, industry, and other laboratories on many unclassified projects. More generally, we are part of the international science and technology community and depend on interactions with others to be cognizant of major advances and to acquire special expertise needed to accomplish mission goals.

Increased Awareness of Security Issues. The report of the Select Committee on U.S. National Security and Military/Commercial Concerns with the People's Republic of China (the Cox Committee) greatly raised public awareness of foreign intelligence-gathering efforts at the DOE national security laboratories, damaging incidents that have occurred, and major deficiencies in the system for dealing with the threat. The Clinton Administration is in agreement with "the overwhelming majority" of the 38 recommendations of the Cox Committee. At the time the report was released in May 1999, many key reforms had already been taken in response to Presidential Decision Directive (PDD) 61, issued in February 1998, and the preliminary findings of the Cox committee helped to accelerate implementation.

PDD-61 ordered the DOE to establish a stronger counterintelligence program and called for more extensive security reviews, a beefed-up cyber security plan, an improved screening process for foreign visitors from sensitive countries, and an increase in the counterintelligence budget. For FY 2000, the program is budgeted at nearly $40 million, an increase from $2.6 million in 1996. At Livermore, the SAFE program, even as it undergoes improvements, is serving as an example for the development of DOE-wide counterintelligence programs and procedures. We are also taking steps to improve cyber and physical security at the Laboratory.

An Extensive Security Apparatus. An extensive security apparatus is in place at Livermore. In the area of physical security, our defense-in-depth approach includes a system of clearances, badging, and background checks; physical barriers and access control to protect sensitive and classified assets; and a fully trained and accredited security force. In addition, a vigorous Operations Security (OPSEC) program serves to identify potential "open" pathways to sensitive information in Laboratory operations and recommends cost-effective countermeasures to deny exploitation.

A defense in layers also characterizes cyber security at the Laboratory. Our classified computer and unclassified computer networks are totally separate. All terminals connected to the classified system are secure, and access to information on the classified system is on a need-to-know basis. For unclassified computers connected to the outside world, we provide protection against intrusion, monitor traffic, and respond to incidents. Moreover, Livermore's Computer Incident Advisory Capability provides on-call technical assistance to DOE sites and other government agencies facing computer security incidents, such as break-ins, attempted break-ins, viruses, and scans by outsiders.

Livermore's counterintelligence program, SAFE (for Security Awareness for Employees), was established in 1986 and has grown in response to the Laboratory's increasing number of foreign interactions, particularly lab-to-lab programs. SAFE—largely staffed by former FBI special agents—works closely with the FBI and is well integrated into the U.S. counterintelligence community.

Strategic Thrusts

Upgrades to Physical Security. The Laboratory annually prepares a comprehensive Site Safeguards and Security Plan, predicated on the DOE Design Basis Threat, that details the computer, physical, and procedural measures we are taking. In general, the physical security of the Livermore site (and Site 300) is maintained through a multilevel, graded approach to limit access and protect information. In response to evolving security requirements, the Laboratory continues to make physical security improvements.

We are taking specific actions to ensure that the Laboratory is fully compliant with all DOE security requirements and sets performance standards exceeding those of our peers. In a recent safeguards and security assessment, a specific issue arose because of a deficiency in procedures. We were unable to meet inventory monitoring requirements because the Plutonium Facility was shut down to address safety concerns, preventing monitoring and measurements. The facility has been reopened, we have resumed all special nuclear material measurements and inventory monitoring, and we are now compliant with DOE requirements.

We have made important technical upgrades to the Perimeter Intrusion Detection and Alarm System (PIDAS) that surrounds our Superblock, which contains our Plutonium Facility, to provide early detection of both airborne and bridging attacks. The Laboratory has committed additional officers to the Superblock and taken other compensatory measures to assure the security of our special nuclear material assets. In particular, we have recruited and put in place an offensively trained Special Response Team having the training necessary to implement a recovery or recapture action. Over 100 simulations of adversary attacks have been completed, and we are continuing to refine our simulation methodology, attack scenarios, and defensive strategies. An external advisory group of expert senior former military experts has been engaged to advise us in this work.

We also continue to pursue technological innovations, such as sophisticated detection systems and the automated portals developed at Livermore to minimize costs. Our automated portal system (Argus) has been adopted as a DOE standard and is being installed at other facilities.

Attention to Security Procedures for Foreign Interactions. Physical security measures are augmented by a system of security controls that apply to day-to-day operations and specific issues that are raised by foreign nationals' visits to the Laboratory and assignments here. It is a graded approach depending whether or not the visitor has connections with a sensitive country. We have in place a standard security plan for visitors, we conduct indices checks and develop detailed visit-specific plans when warranted, and we conduct periodic operations security assessments.

A particular area of attention is the development of a list of sensitive unclassified topics to be used as a basis for evaluating proposed foreign visits and assignments. The purpose of the list is to identify those unclassified topics and technologies that potentially include sensitive information that can be disseminated only after careful review. We are working with DOE's Office of Counterintelligence and the other national laboratories to finalize a sensitive unclassified topics list. The effort is similar to recent activities in which Livermore and other laboratories prepared export control guides to assist employees involved in DOE- and other agency-sponsored collaborations with Russian and former Soviet scientists.

Highest Standards of Computer Security. Recent concerns about espionage involving computer-based information and codes spurred a thorough reassessment of computer security at the Laboratory. We stood down all classified computers (and colocated unclassified machines) as employees went through intensive retraining in cyber security, and computer security experts developed an upgraded Livermore Information Security Plan for DOE approval. Every computer work area and environment was evaluated, and changes were made as necessary to ensure that the Laboratory's classified and sensitive computing meets the highest standards of information security.

In April 1999, Secretary of Energy Richardson approved the Tri-Lab INFOSEC Action Plan, which details nine action items that each of the DOE national security laboratories will take (or have already taken) to improve protection of its computer systems. We are in the process of implementing the plan. For example, we are taking additional steps to ensure that individuals are not able to transfer information from classified to unclassified computers. We are also installing additional "firewalls" within our unclassified network to separate fully accessible information from unclassified sensitive information.

More generally, we are supporting the Secretary's cyber security initiative and are contributing to DOE-wide information security planning. Leading-edge cyber security is vital to our programmatic missions and is an area where we can leverage our expertise to enhance national security in the broadest sense. We are using our computer security upgrade as an opportunity to apply our multidisciplinary approach to science and technology to become a model for computer security.

A Vigorous Counterintelligence Program. Livermore's counterintelligence program (SAFE) develops threat assessments for the Laboratory, reviews visits and assignments by foreign nationals, and runs a vigorous Laboratory-wide counterespionage awareness program. SAFE was reviewed by DOE's head of counterintelligence in April 1998 and identified as a model for similar programs throughout the DOE.

We proactively continue to expand SAFE and improve its capabilities so that the Laboratory's security measures stay ahead of increasingly challenging espionage threats. For example, we have developed, tested, and installed the Visitor Tracking System for use at Livermore. Information on each foreign visit and assignment is entered into the system as part of the review and approval process. The database automatically captures numerous pieces of information about each visit and assignment and can provide statistics as needed. We also continue to upgrade our extensive employee espionage awareness programs. The SAFE staff provides briefings and debriefings for personnel who host foreign visitors or travel abroad and sponsors Laboratory-wide presentations on espionage-related topics by guest speakers from the U.S. intelligence community.

5.3 Laboratory Personnel

Livermore's principal asset is its quality workforce. The Laboratory seeks a highly talented, productive, motivated, flexible staff that is committed to Livermore's goals and reflective of the diversity of California and the nation. We strive for a work environment in which all employees can contribute to their fullest and feel valued for their role. The size, job classification, and diversity of Livermore's career-employee workforce are characterized in Tables 5-2 and 5-3.

Recruitment, reward, and advancement policy decisions are based on contribution to Livermore's success. The Laboratory greatly values outstanding scientific and technical achievements. Breakthrough accomplishments are critical to the success of Livermore's programs and provide the foundation for future programs to meet national needs. The Laboratory's programmatic achievements would not be possible without safe and efficient operations. All activities depend on the dedicated, high-quality efforts of Laboratory employees engaged in administrative and operational support. In both scientific work and operational support activities, we recognize and reward both individual and team excellence in performance. And we expect all employees to take pride in and responsibility for their work, improve their skills, and continue their professional growth.

Situation and Issues

Strong Bond with University of California. Challenging scientific programs, world-class research facilities, and a collegial environment are critical to attracting and retaining an outstanding workforce. For the technical staff, the

Table 5-2. Laboratory staff composition as of March 31, 1999 (excludes summer hires and temporary program participants; may include indefinite employees).

		Management		Scientific		Administrative		Technical		All others		Totals	
			(%)		(%)		(%)		(%)		(%)		(%)
White	M	821	(66.3)	1440	(71.3)	154	(25.0)	1020	(66.6)	420	(33.0)	3855	(57.7)
	F	239	(19.3)	271	(13.4)	332	(53.9)	232	(15.2)	524	(41.2)	1598	(23.9)
Black	M	30	(2.4)	23	(1.1)	8	(1.3)	41	(2.7)	44	(3.5)	146	(2.2)
	F	9	(0.7)	13	(0.6)	24	(3.9)	13	(0.8)	34	(2.7)	93	(1.4)
Hispanic	M	40	(3.2)	46	(2.3)	9	(1.5)	88	(5.7)	72	(5.7)	255	(3.8)
	F	24	(1.9)	8	(0.4)	31	(5.0)	16	(1.0)	87	(6.8)	166	(2.5)
Native American	M	11	(0.9)	8	(0.4)	5	(0.8)	20	(1.3)	16	(1.3)	60	(0.9)
	F	6	(0.5)	0	(0.0)	10	(1.6)	11	(0.7)	12	(0.9)	39	(0.6)
Asian	M	33	(2.7)	152	(7.5)	13	(2.1)	63	(4.1)	30	(2.4)	291	(4.4)
	F	22	(1.8)	47	(2.3)	30	(4.9)	22	(1.4)	33	(2.6)	154	(2.3)
Total Minority	M	114	(9.2)	229	(11.3)	35	(5.7)	212	(13.8)	162	(12.7)	752	(11.3)
	F	61	(4.9)	68	(3.3)	95	(15.4)	62	(4.0)	166	(13.1)	452	(6.8)
Unidentified	M	3	(0.2)	12	(0.6)	0	(0.0)	5	(0.3)	0	(0.0)	20	(0.3)
	F	0	(0.0)	1	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	1	(0.0)
Totals	M	938	(75.8)	1681	(83.2)	189	(30.7)	1237	(80.8)	582	(45.8)	4627	(69.3)
	F	300	(24.2)	340	(16.8)	427	(69.3)	294	(19.2)	690	(54.1)	2051	(30.7)
Lab totals		1238		2021		616		1531		1272		6678	

Table 5-3. Laboratory staff composition as of March 31, 1999 (excludes summer hires and temporary program participants; may include indefinite employees).

	None	AA	BA/BS	MA/MS	PhD	Total Pop
Management	314	132	211	261	320	1,238
Scientific Professional	31	4	483	588	915	2,021
Administrative Professional	248	45	203	103	17	616
Technical jobs	751	509	250	20	1	1,53
Other jobs	1,040	160	68	4	0	1,272
Totals	2,384	850	1,215	976	1,253	6,678

Laboratory provides creative research opportunities and an association with University of California that has led to an array of scientific and technical ties to academia that would not have been achievable otherwise. More generally, all employees have the opportunity to work with world-class peers and to make a difference by contributing to the solution of difficult real-world problems where the national interest is at stake. The strong bond between Livermore and the University nurtures an atmosphere at the Laboratory in which independent views and technical honesty are core values. University of California management of Livermore also provides employees an excellent benefits package and the underlying policy framework for the Laboratory's human resources program.

Recruiting and Retaining High-Quality Employees. In spite of these competitive advantages, we must be more aggressive in policies and practices designed for recruitment and career development in selected disciplines where there is significantly increased competition for the best people and where demand far outpaces supply. The Laboratory's recruitment strength has been based on the work environment, the importance of the national security work, and the exciting technical challenges Livermore has been able to offer. However, compensation is also an issue. Although the Laboratory's compensation system is structured to recognize superior performance and is driven by the "market," it is not as flexible as some systems in private industry. In certain "hot" skills job classifications, such as computer scientists and optical engineers and technicians, the Laboratory cannot easily match the total compensation offered by others, particularly in the highly competitive San Francisco Bay Area.

A Skilled and Flexible Workforce. Our goal is an employee population with the motivation, innovation, and diversity needed for Livermore to excel in its mission. We must also retain a degree of flexibility in staffing. Program redirections will continue to occur as the nation continues to adjust to changing requirements for national security, energy security, and environmental quality.

Workforce issues must be managed in a way that helps employees adapt to changing needs and encourages skills development while it keeps employee dislocations to a minimum. The Laboratory therefore should continue to balance efforts between being a storehouse of skills and a purchaser of skills. To be more agile in managing shifting workforce demands, we have added a new Flexible Term employment category, improved workforce planning processes, and continue to upgrade employee development and placement programs. In addition, we must increase emphasis on leadership training because the Laboratory's future depends on the continual development of leaders who are visionary, skilled in managing and building programs, and sensitive to workforce needs.

Strategy Thrusts

Implementing Contemporary Personnel Practices. The Laboratory is reviewing its personnel practices (e.g., compensation, benefits, work environment, and services) and is implementing changes that enhance the Laboratory's ability to attract and retain employees as well as encourage their growth. A contemporary work environment requires both appropriate policies and attention to implementation, including equity in compensation and other personnel practices, effective and fair complaint resolution processes, recognition of the importance of balancing work and family needs, and means for assuring that employees feel well informed and have a shared sense of excitement about the success of the Laboratory.

One area of particular attention is compensation. We are working with—and have benefited from exceptional support from—the DOE to ameliorate difficulties in the "hot" skills areas by adjusting the compensation system, where possible, to address the most critical problems. For example, as part of the merit increase package in FY 1998, we supplemented by 10% the salaries for computer scientists, whose skills are in great demand in the San Francisco Bay Area. Further increases were provided in FY 1999, and the Director set aside part of the approved salary package to be used by the directorates for their internal hot skills and/or internal alignment problems. More generally, we continue to monitor and analyze compensation practices of other institutions for potential augmentation to the Laboratory's all-base compensation system, where appropriate.

Planning for Future Needs. Projections for long-term workforce needs are now being guided by a more formal workforce planning process that is used to shape staffing and sizing decisions. For each of the past several years, the process has included one or more Workforce Day planning meetings that include the Laboratory Director and his senior management team. These meetings involve discussion of key issues (such as hot skill areas and hiring challenges), provide a Laboratory-wide review of workforce data, and result in an update to an institutional hiring plan that is consistent with Livermore's strategic plan. Progress on the approved hiring plan for each directorate is monitored on an ongoing basis by the Director's Office.

Workforce Diversity. Workforce plans consider both programmatic needs and institutional goals, such as achieving a workforce that is reflective of the rich diversity of California and the nation. We have developed and are working to implement plans to increase the representation of minorities and women in the Laboratory's workforce. A focal point for our efforts to ensure equal employment opportunity and workforce diversity is the Laboratory's Affirmative Action and Diversity Program (AADP). In addition to monitoring compliance with relevant executive orders and legislation, AADP develops the Laboratory's action plans to increase diversity, sponsors a variety of outreach programs, and interacts with employee network groups to foster strong working relationships among these diverse associations. AADP provides funds to these groups to promote cultural awareness and matching scholarship funds to eligible, federally protected groups. For a summary of AADP's broad range of activities, see their Web page, www.llnl.gov/aadp/zindex.html.

Employee Development. The Laboratory's workforce plans set recruiting requirements for various skill areas and provide areas of emphasis for employee development. The Laboratory supports training, education, and career development programs for individuals that meet their needs for growth and are consistent with short- and long-term Laboratory goals. We must ensure that employees have the best skills, training, and tools to accomplish their current work and to prepare for future assignments. Many career development and training resources are now made more easily available to employees through the Laboratory's internal Web page, including links to

- Training Programs and Organizations, including information on the Laboratory's many training programs and organizations and links to DOE training.
- Training Resources, including course catalogs, mentoring and self-directed learning resources, and online training courses.
- Career Development Resources, including information on the Career Center, career management, and employment opportunities.
- Academic Programs, including information on degree programs, coursework, undergraduate scholarships, academic assistance, onsite university programs, and Laboratory TV courses.
- Training Documents, including online resources and contact information.

Leadership and Management. A particularly area of new emphasis has been training for supervisors. We have fully implemented two levels of supervisory training, one for new supervisors and one for all first-level supervisors across the Laboratory. These programs are designed to assure that all supervisors understand their full responsibilities, as well as Laboratory policies and procedures, and to develop solid leadership and people skills. The program has been so successful that some managers for whom the training is not required have chosen to attend as a refresher and/or to enhance their skills. Management training is being expanded to include a management institute for division leaders and higher managers and a series of televised presentations by nationally known management "gurus" augmented by live, facilitated discussions.

5.4 Facilities and Plant Infrastructure

Lawrence Livermore National Laboratory comprises two sites: the main Livermore site and Site 300, a 28-square-kilometer remote explosives test facility located about 25 kilometers southeast of Livermore. The Livermore site has 170 permanent buildings and 331 temporary structures and houses over 9,000 people. At Site 300, there are 66 permanent buildings and 10 temporary structures. The replacement plant value is estimated to be $3 billion, which does not include some $1.8 billion in personal property and land value (see Figures 5-1 through 5-3 and Tables 5-4 through 5-6).

Stewardship of DOE lands and facilities at Livermore is an important responsibility. We have world-class scientific facilities that are essential for national security and provide unique capabilities to meet other enduring national R&D needs. Facilities and infrastructure—and our investment strategy for maintenance, renovation, and new construction—must be aligned with the Laboratory's programmatic and operational requirements.

We want every employee to take pride in Livermore's campus setting—a physical plant that is attractive, accessible, and designed to be cost effective and inviting. This goal requires modern facilities at the Laboratory, designed and sized for current and future operations and well maintained at competitive costs. A quality campus environment attracts top-notch employees, enhances workforce productivity, and helps ensure programmatic success.

Situation and Issues

Upgrades and New Construction. At the core of the Laboratory's strength in facilities are unique, state-of-the-art, experimental research facilities. The major national security directorates all have some modern core facilities in use or under construction. Construction is in progress on the National Ignition Facility, which will be a cornerstone of the nation's nuclear weapons stockpile stewardship program. In addition, planning is under way for the Terascale Simulation Facility to house the Laboratory's ASCI computers and needed office space for the program. The modern office space designed into these research facilities—and the space in other recently constructed facilities at the Laboratory—helps to improve the overall living conditions of the Laboratory population. Recent actions, such as line items for electrical and infrastructure modernization, have also helped upgrade the Livermore site. In addition, the communications and information systems infrastructure at the Laboratory has undergone continual upgrade, in part to keep pace with the unprecedented high-performance computing capability that Livermore is acquiring.

Rehabilitation and Replacement. On the other hand, many structures are 30 to 50 years old and need rehabilitation or replacement (see Figure 5-1). These conditions place stress on strategic management of facilities and site planning, which must balance the needs and resources for maintenance, facility rehabilitation, and new facilities development.

To keep our aging facilities operational, we continually update a prioritized list of institutional maintenance requirements (Figures 5-2 and 5-3.) Only half of our employees currently reside in permanent space, and the majority of temporary office space is nearing or already beyond the end of service life. As more facilities age beyond their intended life, our need for modern office space will continue to grow. In addition, from long-discontinued programs, we have outdated and unusable laboratory space that must be decommissioned, decontaminated (where necessary), and demolished. Livermore's legacy facilities and other excess marginal space require considerable up-front investment to rectify or demolish.

Strategy Thrusts

An Institutional Focal Point. Appointed in 1997, the Institutional Facility Manager serves as the focal point for developing and implementing a long-term strategy for managing facility investments at Livermore. The IFM office works with senior managers from each Laboratory organization to establish priorities for new facilities, maintenance and backlog reduction, and space reduction. By having a focal point for working facility management issues, the Laboratory is increasing its effectiveness in focusing investments to mission priorities and in meeting essential institutional demands.

A Balanced Portfolio for Site Revitalization. The Laboratory is following a balanced approach to facility management, with the goal of assuring the future vitality of the Laboratory as an institution and of its primary missions. In particular, a coherent Laboratory-wide office requirements plan is being continually refined to address the needs of the nearly 3,000 employees who work in inadequate space—trailers, modular units, or World War II-era buildings. Four principal elements of the plan are:

- Construction of new facilities.
- Rehabilitation of older facilities, where cost effective.
- Prioritization and reduction of deferred maintenance backlog.
- Efficient management of legacy facilities.

New Technical Facilities. New technical facilities at Livermore are being constructed through DOE program investments. Two particular major new technical facilities—the National Ignition Facility and the Terascale Simulation Facility mentioned above—are the Laboratory's highest priorities. The scheduling of many of the nontechnical-facility Line Item Construction projects is a product of: (1) the priorities that the Laboratory has set on each project, and (2) discussions among the three DOE national security laboratories and DOE Defense Programs to make most

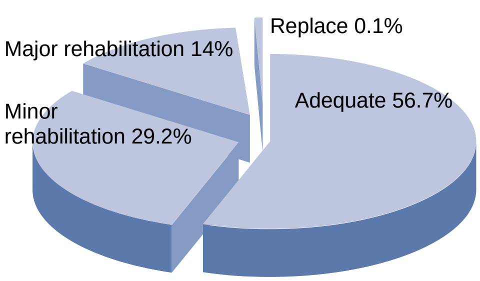


Figure 5-1. Condition of Laboratory space

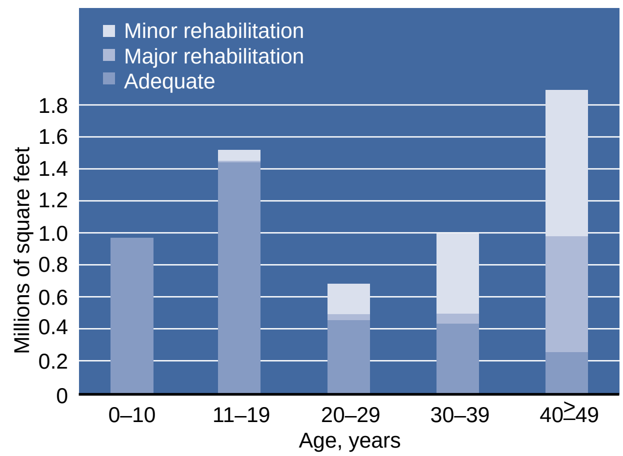


Figure 5-2. Age and condition of Laboratory buildings.

effective use of overall funding.

Rehabilitating Older Facilities. To meet the greater portion of the Laboratory's office space needs, we are rehabilitating our older facilities to provide adequate quality office space where cost effective. Depending on the return on investment, older but fundamentally sound facilities are being returned to "good" condition by maintenance rehabilitation projects. In this connection, we are pursuing workable options for innovative, cost-effective, facility revitalization and new construction/renovation. A pilot project is under way to bring one of the World War II-era building complexes (B314/315), which has over 100 offices, up to good condition (an additional 15 years of life) at a very affordable cost. In addition, space in a large open-bay building (T-1879) was rehabilitated and modified into four large, well-designed and well-equipped classrooms that meet the specific needs of the Laboratory's teaching organizations. Two additional projects are planned, including the rehabilitation of trailers in the 1400 block to affordably provide an additional 200 good office spaces.

Reducing the Maintenance Backlog. We have developed and are using a planning process to better prioritize work to reduce deferred maintenance backlog. Priorities are set by considering both probability of failure (in the absence of maintenance) and the level of risk to the Laboratory's mission if there is a failure. Projects that rank highest in both criteria are "A list" items that require immediate attention. Other deferred maintenance projects fall into less critical categories: "B" items (to address within one year), "C" items (to address in about two years), and even lower priority categories (D through F). Available funding sources are being applied to deal with the "A" and "B" list items, which totaled about $15 million in FY 1999.

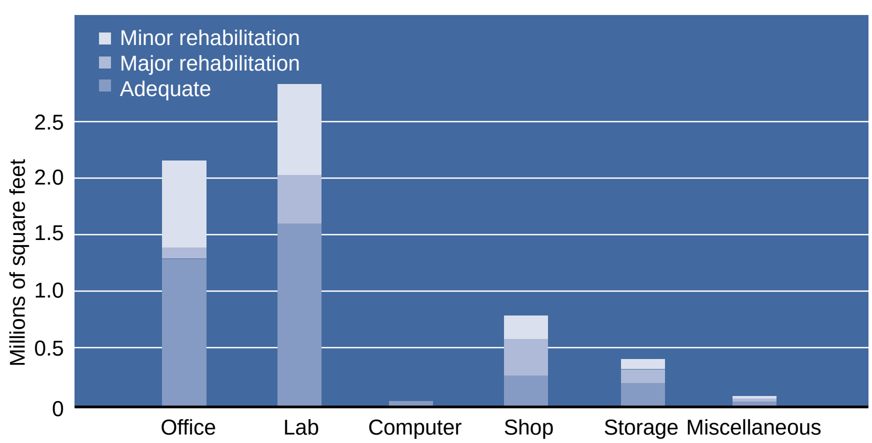
Managing Excess and Legacy Facilities. Until funds are available for restoration and reuse or deactivation and demolition, institutional funding is used to manage legacy facilities at a low-cost configuration consistent with ES&H requirements. In a pilot project completed in FY 1999, we demonstrated safe and cost-effective demolition of contaminated (chemistry science) facilities at the Livermore site that totaled about 8,200 square feet. There were no incidents, injuries, or lost/restricted workdays in this highly successful project, which included a thorough implementation of Integrated Safety Management as part of the work plan. Through the use of state-of-the-art sampling, near-real-time chemical and radiological analysis, and highly precise removal of contaminants, we were able to minimize radioactive and conventional hazardous wastes. About 1,100 tons of reinforced concrete and all conventional materials were recycled at no disposal cost. Nearly an acre of unrestricted-use real estate is now available in the core area of the Laboratory.

Facility Plans and Resource Requirements

Table 5-6 (page 5-14) provides a summary of funded and proposed construction projects at the Laboratory with total estimated cost (TEC) in excess of $5 million. Construction projects that are funded or are proposed to begin in FY 2001 or 2002 include:

Sensitive Compartmented Information Facility (SCIF) (FY 2001 start; TEC: $24.0 M). The new Sensitive Compartmented Information Facility (SCIF) is proposed as a two-story 5,400-square-meter building to be sited on the west side of the Laboratory, adjacent and north of Building 132. The new SCIF is essential for the Nonproliferation, Arms Control, and International Security Directorate (NAI) to continue to carry

Figure 5-3. Use and condition of Laboratory space.



out its mission by providing major enhancements in information management, optical-fiber networking, storage and retrieval, and real-time communications with DOE and the intelligence community. In addition, by consolidating Livermore's national security programs in a new advanced facility, maintenance and special security costs will be reduced.

Protection of Real Property—Phase II (FY 1999 start; TEC: $19.9 M). This project includes roof reconstruction of 11 major Laboratory buildings (Buildings 111, 113, 121, 141, 194, 231, 241, 251, 281, 321, and 332) with a combined area of about 52,000 square meters. These buildings perform functions vital to the Laboratory's capability to support the Stockpile Stewardship Program. Reconstruction of these roofs is an investment that will extend the useful life of these facilities for at least 20 years. This reconstruction project has been identified as the highest-priority work to upgrade facilities for the protection of critical weapons facilities at the Laboratory.

Isotope Sciences Facility (FY 1999 start; TEC: $17.4 M). This project provides for a seismic retrofit to the Isotope Science Facility (Building 151) and construction of an office addition, retrofit of ventilation systems in Buildings 151 and 154, decontamination of the Refractory Materials Facility (Building 241), and disposal of existing trailers. Work conducted in the Isotope Sciences Facilities plays a key role in fulfilling the Stockpile Stewardship Program mission to annually certify nuclear weapons performance, provide important diagnostics to evaluate the performance of NIF/ICF capsules, and maintain the ability to resume nuclear testing.

Rehabilitation of the Maintenance Facility (FY 1999 start; TEC: $7.9 M). The purpose of this project is to renovate Livermore's principal maintenance and repair facility, Building 511. This 56-year-old facility is badly deteriorated and requires renovation to maintain a state of readiness for ensuring that critical maintenance and infrastructure support activities can be accomplished. Major features of the project include a new weathertight exterior shell including new windows and a main entry, elevator, restroom upgrades, ventilation for shop areas, and updates to the fire-protection and electrical systems.

Terascale Simulation Facility (TSF) (FY 2000 start; TEC: $83.5 M). The project provides for the design, engineering, and construction of the Terascale Simulation Facility (TSF - Building 453), which will be capable of housing the 100 teraops-class computers required to meet the Accelerated Strategic Computing Initiative (ASCI). The building will encompass approximately 25,000 square meters. The building will contain a multistory office tower with an adjacent computer center. The Terascale Simulation Facility (TSF) proposed here is designed from inception to enable the very large-scale weapons simulations essential to ensuring the safety and reliability of America's nuclear stockpile. The timeline for construction is driven by requirements coming from the ASCI portion of the Stockpile Stewardship Program. The TSF will manage the computers, networks, data, and visualization capabilities necessary to store and understand the data generated by the most powerful computing systems in the world.

Engineering Technology Complex Upgrade (FY 2002 start; TEC: $21.7 M). The Building 321 Engineering Technology Complex will be upgraded and remodeled to make its four-decades-old shop facility capable of providing state-of-the-art service to the programs for at least the next 25 years. The complex will be upgraded to contain precisely controlled temperature, vibration, and cleanliness environments. Three wings of Building 321 will undergo structural retrofit to meet current seismic standards. Fabrication activities performed in the Building 321 Complex are critical to the success of the Stockpile Stewardship Program, the National Ignition Facility, and most other Laboratory programs.

Decontamination and Waste Treatment Facility (FY 1986 start; TEC: $62 M). The Decontamination and Waste Treatment Facility (DWTF) will enhance, improve, and expand

Table 5-4. Laboratory space distribution.

Type of space	Area: Square feet	Area: Square meters
Main site	5,732,000	532,714
Leased-university	0	0
Leased-off-site	92,000	8,550
Site 300	332,000	30,855
Total	6,156,000	572,119

Table 5-5. Facilities replacement value (in millions of dollars).

	Buildings	Trailers	Other structures	Utility/infrastructure	Total
Livermore Site	1,788	80	3	951	2,823
Site 300	105	1	12	103	221
TOTAL	1,893	81	15	1,054	3,044

hazardous waste and mixed waste management at the Laboratory through the construction of approximately 7,300 square meters of new state-of-the-art facilities for decontamination and waste treatment processes and 470 square meters of modifications to an existing building. DWTF will provide new, centralized, and integrated facilities for hazardous waste management operations that will meet the requirements for a Low Hazards Category 3 facility. This project will continue to meet the goals of Livermore's waste management program while significantly enhancing the waste management capabilities.

Adaptive Re-Use for Office Space (FY 2003 start; TEC: $24.0 M). The proposed project would renovate and modify existing laboratory space into general-purpose office space and support areas. A substantial percentage of the office space at Livermore is currently made up of aging trailer space that is rapidly deteriorating. Instead of replacing these offices with new construction, the goal is to reuse existing facilities that have little or no current mission. Adaptive reuse provides a sensible means of recovering what would become legacy space.

5.5 Support Services

Programmatic work at the Laboratory is supported by business, procurement, financial, and a variety of other types of services. Livermore is making considerable improvements in its operational support for programs,

Table 5-6. Funded and proposed construction (in millions of dollars).

Project Title	TEC $M	FY1998	FY1999	FY2000	FY2001	FY2002	FY2003	FY2004	FY2005 & beyond
Defense Program - Funded Projects:									
National Ignition Facility	1045.7	197.8	284.2	248.1	TBD[a]	TBD	TBD	TBD	TBD
S-300 Contained Firing Facilities	49.7	19.3	6.7						
Protection of Real Prop (roofs) Phase I	7.8	4.8							
S-300 Fire Station and Medical Facility	5.4	0.9	4.5						
Total DP Funded Construction[b]		222.8	295.4	248.1					
Defense Program - Proposed Projects and Newly Started Projects:									
Protection of Real Property - II	19.9		2.5	2.4	2.8	2.8	9.4		
Isotope Sciences Facility	17.4		2.0	2.0	5.0	4.4	4.0		
Rehabilitation of Maintenance Facility	7.9		4.0	3.9					
Terascale Simulation Facility	83.5			8.0	20.0	23.0	23.0	9.5	
Engineering Technology Complex Upgrade	21.7					2.0	4.0	9.0	6.7
Adaptive Re-Use for Office Space	24.0						3.0	11.0	10.0
Site 300 HE Machining Facility	44.0								4.0
Total DP New Funding Requirements			8.5	16.3	27.8	32.2	43.4	29.5	20.7
Total Defense Programs Construction[b]		222.8	303.9	264.4	27.8	32.2	43.4	29.5	20.7
Nonproliferation and National Security - Proposed Projects:									
SCIF Area for NAI	24.0				5.0	16.0	3.0		
Energy Research - Proposed Projects:									
B-543 Addition	18.2						3.5	10.7	24.0
EM Projects - Funded Projects:									
Decontamination/Waste Treatment Facility	62.4	11.3	3.7	2.0	2.0	0.7			
Total Laboratory Construction Projects[b]		234.1	307.6	266.4	34.8	48.9	49.9	40.2	44.7

[a]To be determined.
[b]National Ignition Facility construction estimates are TBD and thus are excluded from FY 2001–2004 totals.

striving to size and manage indirect activities to optimize the overall cost effectiveness and performance. As gauged by performance measures in the UC/DOE contract, Laboratory support functions are of increasing quality, delivered in a timely manner, and priced competitively.

We strive for operational support to be provided in a professional manner and for procedures and systems that are deemed equitable, self-consistent, and supportive of Laboratory values. Good business practices are not the only consideration. As a public-sector organization engaged primarily in contract work for DOE and other federal agencies, the Laboratory conforms to regulatory requirements—an important factor affecting the operations environment. Indirect organizations provide assurance that compliance is managed responsibly and efficiently and in a way that is clearly defensible to the public, to regulators, and to Laboratory programs.

Situation and Issues

Reducing Support Costs. Many improvements have been made to reduce support and overhead costs to make more resources available for direct program work. System and procedure improvements have identified more closely the real cost of activities, thus enabling the Laboratory to explicitly address hidden subsidies. These actions have been taken with a view toward maintaining and improving institutional health and protecting the Laboratory's capability to conduct essential operations, such as in ES&H. Thus far, the Laboratory has increased the spending power of Laboratory programs through a reduction in annual institutional overhead costs of about $50 million between FY 1993 and FY 1998.

Functional elements that are responsible for providing many indirect services Laboratory-wide have undergone significant reengineering to improve efficiency, reduce costs, and improve understanding of customer needs and expectations. We have adopted best commercial practices whenever possible and optimized business information systems to improve communications at all levels. This reengineering has benefited from a major change by the Department of Energy to an outcome-based oversight model for some aspects of operations, a shift to an aggressive self-assessment process, and implementation of meaningful metrics to assess performance. Next steps in the reengineering of Laboratory indirect activities include taking advantage of the opportunities offered by rapid technology change and the major information systems improvements that are now widely available.

Commitment and Teamwork Contributing to Efficiencies. These dramatic improvements in performance have been made possible by the commitment, capability, and productivity of an excellent Laboratory workforce. Through the continuing efforts of Laboratory employees, we will continue to improve the indirect services provided to programs, even in functional areas that have already undergone cost cutting and reengineering. Employees who staff the indirect functions and the customers who use their services must work together to achieve site-wide implementation standards, avoid redundancy in support functions, avoid over-specialization in personnel skills that limit staffing flexibility, and balance short-term gains and long-term benefits when making decisions about overhead and support functions.

Strategy Thrusts

The Laboratory will continuously improve systems and processes for providing indirect services and effectively communicate with and involve both employees and customers in the changed process.

Anticipating Customer Needs. Successful reengineering includes anticipating customer expectations; soliciting continuous customer feedback to assess satisfaction, needs, and understanding of strategies; and continuing aggressive use of industry and government benchmarking to enable effective comparisons and adopt best practices. Reengineering approaches will take advantage of modern information technology, adopting off-the-shelf approaches whenever possible. In some cases, we will rely on institutional reinvestment to absorb short-term expenses that will lead to long-term cost savings. Moreover, our Laboratory indirect organizations will continue to find ways to better meet customer needs through the most appropriate combination of internal and external sources. Where outsourcing is a viable option, organizations should be staffed to take advantage of it.

Balancing Priorities. In planning for and delivering operational support, the Laboratory will strive to balance resource allocations so that programmatic work is performed responsibly, cost effectively, and in compliance with regulatory and other requirements. Implementation of this strategy will also ensure that Laboratory policies permit local flexibility but not to the point where local optimization undercuts compliance or other institutional objectives. For these efforts to be successful, operational support organizations must communicate their vision, goals, and actions in a way that engenders Laboratory-wide support and buy-in. Support by all levels in the organization—senior management through individual contributors—is required to achieve the goals and high standards that we set for operations. Success also requires strengthened partnerships with relevant components of

UC, DOE, other laboratories, and externally sponsored organizations.

5.6 Information Management

Livermore's principal product is scientific and technical information, which we share internally and disseminate widely to sponsors, other researchers, and the general public. We also generate a significant amount of administrative information in conducting Laboratory programs. Improved management of information internal to the Laboratory can enhance internal communications, improve program effectiveness, and help reduce costs. We are working to design and implement a Laboratory computer-based information system that will provide users with improved connectivity, universal compatibility, and intralaboratory interoperability. To be most effective, the Laboratory workforce needs accurate, reliable information in a usable format; secure computer systems; and high-capacity computer networks.

While scientific computing is a leading consideration, business planning, lab-wide communications, and operational processes are partners in the development of an integrated information management plan. These efforts are led by the Laboratory's Chief Information Officer (CIO), appointed in October 1996. The CIO's responsibility is to provide the vision and leadership for the development of an information system architecture for the future, to propose and implement standards for hardware and software, and to develop information system strategies that balance cost, technology, and service.

Situation and Issues

To Link Diverse Computer Platforms and Information. Livermore is currently well positioned in most aspects of its information systems infrastructure. We are a major player in defining the applications and performance requirements of the high-end platforms used in scientific computing. The prime driver for these efforts is DOE's Accelerated Strategic Computing Initiative, which directly supports the Stockpile Stewardship Program. A major long-term issue for distributed scientific computing may be the limitations of the computer networks that link the high-end platforms with the customers throughout the Laboratory. While the Laboratory-wide backbone network is in excellent shape, the wiring and routing equipment within many buildings needs upgrades to support very-high-speed access to the Laboratory's computer systems.

In addition, the Laboratory is accumulating a growing base of experience developing information management systems that point the way to the future. The Nuclear Weapons Information Project is archiving nuclear weapons information (digital information from photos, videos, and documents) to provide users throughout the weapons complex a secure, searchable means to access the data on a need-to-know basis. Also within Laboratory programs, powerful data-management systems are being developed for human genome research, weapons life-cycle design, and eventual operation of the National Ignition Facility.

We have also made great strides in modernizing and reengineering the Business Information Systems structure at the Laboratory, and we have been moving to an electronic Library of the Future. In the Library of the Future, end users can readily obtain the information they seek from computers inside and outside the Laboratory. In addition to making documents available to Internet users, we work with DOE's Office of Scientific and Technical Information to ensure that Livermore's publications are accessible throughout the Department, to other Federal agencies, and to the public.

Strategy Thrusts

Information Architecture for Digital Infrastructure. A committee chartered by the CIO completed in 1998 the development of an Information Architecture (IA) plan for the Laboratory. The architecture is the framework for implementing a digital information infrastructure with well-integrated services and activities—a utility that is Laboratory-wide, secure, reliable, standards-based, and intuitive for users. The IA's interrelated elements support all information processes, including various applications provided through layered hardware and message protocols, system management, and system security. These elements and their interactions are discussed in the plan, as are the current situation, the desired future state, and the steps to get there. As we implement the IA plan, we will be moving from the ad-hoc system to a Laboratory-wide information architecture with information systems that operate flawlessly and transparently, providing Laboratory employees in all organizations ready access to the capabilities they need.

Consolidating Desktop Support. We are also taking steps to consolidate support activities for desktop computer systems and computer networks. This action will help to reduce costs and increase our overall efficiency through more effective management of Livermore's heterogeneous and distributed desktop computing and network environments. We need standard services and practices in place that are accepted and followed by all elements of the Laboratory. Following processes and direction established in the IA plan, we will be responsible for defining, documenting, and implementing Laboratory wide a consistent and effective set of distributed desktop computing and network support services and processes.

5.7 Internal and External Communications

The Laboratory is a national resource center of applied science and technology. In this role, we serve diverse customers and strive to meet the needs of many stakeholders. These interactions range from the broad scientific community and the leaders of the federal government to our own local community and Livermore employees.

Through efforts of senior management and the Public Affairs Office (PAO), Livermore has improved internal and external communications by bringing the Laboratory's messages to important audiences and seeking the concerns and comments of those audiences. Internally, the Laboratory needs effective communications to support dialogue on key issues, senior management decision making, and dissemination of institutional information. Externally, the Laboratory is striving to be seen locally, nationally, and internationally as a credible and authoritative source on issues relevant to our mission. We want to be perceived as an intellectual asset and a helpful neighbor in the Bay Area and California, and we want the communities around us to be proud we are here.

Situation and Issues

Listening to Our Customers. The Laboratory's communications systems ensure that customers and stakeholders are identified and their concerns are considered in the Laboratory's leadership, decision-making, and planning processes as well as in the formulation of operational policies. For example, input was broadly sought in preparing *Creating the Laboratory's Future*. The document, which put forth Livermore's vision, goals, priorities, values, and strategy, was widely distributed to both external and internal audiences.

Improving Community Relations. The Laboratory engages in considerable outreach with stakeholders and customers and makes extensive use of participatory forums. Enhanced outreach efforts by both the Director's Office and PAO this past year have resulted in improvements in Laboratory public affairs and community relations. The director for communications instituted several changes within PAO in response to the results of surveys conducted with employees, the local community, media, and others. PAO is now taking a more integrated and strategic approach to communications, with a focus on senior management attention to and involvement in communications planning and implementation.

Strategic Thrusts

Information Outlets. The Laboratory is making use of rapid advances in technology to improve internal communications and external communication with the general public, local and regional audiences, and leaders in the federal government. We are using the Internet for rapid internal communication and for institutional publications. For example, the Laboratory newspaper *Newsline* now has an online version (*NewsOnLine*) that is issued twice weekly. *Newsline* and *Grapevine* (the Laboratory's internal Internet home page) carry a "From the Director" column, which provides employees with information about key institutional efforts and Laboratory issues.

Online Communications. Institutional publications, such as *Creating the Laboratory's Future*, *Science & Technology Review*, the *Laboratory Annual Report*, and the *Institutional Plan*, are available on the Laboratory's external home page. These publications have been redesigned to make the information more accessible to general audiences. More generally, Livermore's external home page is a national resource of science and technology information. Many publications are available online, and information is provided about our operations and programs, as well as opportunities for employment and research partnerships.

Involvement in Various Community Programs. In the local community, the Director and other senior managers have increased their visibility through more frequent meetings with local officials and civic groups.

For the local Chamber of Commerce, Rotary, and Tri-Valley Science Fair, Livermore senior managers serve as board members representing the Laboratory. They also participate in ongoing activities of Tri-Valley business councils and economic development leadership committees, serve as the spearhead for memoranda of understanding between the Laboratory and nearby community colleges in the field of workforce development, and participate in a youth summit, Livermore's Promise: Alliance for Youth, which is an offshoot of General Colin Powell's national effort.

Furthermore, as a Superfund site, Livermore participates in a national program on health assessment conducted by the Agency for Toxic Substances and Disease Registry. We are involved in community meetings focused on public health issues about Laboratory environmental restoration activities and operations.

SECTION 6

Appendices

A Livermore team of scientists, engineers, and technicians has demonstrated a different approach to the concept of a magnetically levitated train, called Inductrack. NASA has awarded Livermore a three-year contract for exploring the concept as a part of a system to more efficiently launch satellites into orbit. Inductrack, first tested on a one-twentieth-scale model of a linear track and test cart, performed consistent with accepted theory, and the current prototype is currently being developed to run at "Xtreme" speeds up to Mach 0.5.

6.1 Program Resource Requirement Projections

Data for FY 1998 are taken from the FY 1998 LLNL Budget Office Annual Report. Data for FY 1999 through FY 2001 represent a combination of the FY 2001 Field Budget Submission and the FY 2001–2002 Defense Programs Field Budget Estimates (April 1999). The guidance case is used for all programs. The resource data for FY 1998 through 2004 are based on the following:

- FY 1998 through 1999, actual budget obligations and authority.
- FY 2000 through 2004, Program Managers' estimates of resource requirements.
- Inflation factor: for FY 2000 and 2001, inflation is 4.0%; for years beyond FY 2001, resources requirements are expressed in constant FY 2001 dollars.
- Personnel figures do not always add correctly because the numbers have been rounded to whole numbers.

The program resource projections are shown as follows:

- Table 6.1-1. Laboratory funding summary.
- Table 6.1-2. Laboratory personnel summary.
- Table 6.1-3. Resources by major DOE program.
- Table 6.1-4. Resource projections by sponsor for non-DOE reimbursable programs.
- Tables 6.1-4 through 6.1-17. Detailed resource breakouts by DOE sponsors.

Table 6.1-1. Laboratory funding summary (in millions of dollars).

	FY 1998 BO	FY 1999 BA	FY 2000[a] BA	FY 2001[a] BA	FY 2002[b] BA	FY 2003[b] BA	FY 2004[b] BA
DOE Effort	780.6	748.1	837.9	899.6	895.0	895.0	895.0
Work for Others	82.0	74.2	80.4	84.3	84.3	84.3	84.3
Work for Non DOE	160.7	206.9	217.0	189.5	189.5	189.5	189.5
Total Operating	1023.3	1029.2	1135.3	1173.4	1168.8	1168.8	1168.8
Program Capital Equipment	16.5	11.8	7.4	6.7	6.8	6.8	6.8
Program Construction[c]	183.6	312.5	226.4	29.8	30.9	23.0	23.0
General Purpose Facilities	0.0	0.0	0.0	0.0	0.0	0.0	0.0
General Plant Projects	7.9	10.1	10.5	5.9	0.3	0.3	0.3
General Purpose Equipment[d]	7.8	7.8	7.8	7.8	7.8	7.8	7.8
Total Laboratory Funding[c]	1231.3	1363.7	1419.6	1215.8	1206.8	1198.9	1198.9
Proposed Construction	0.0	0.0	0.0	5.0	16.0	1.5	1.5
Total Projected Funding[c]	1231.3	1363.7	1419.6	1220.8	1222.8	1200.4	1200.4

[a]4.0% escalation FY 2000 and 2001.
[b]FY 2002 and beyond in constant FY 2001 dollars.
[c]National Ignition Facility construction estimates are TBD and thus are excluded from FY 2001–2004 totals.
[d]Not included in total lab funding because funding is collected as a distributed budget.

Table 6.1-2. Laboratory personnel summary (in full-time employee equivalent).

	FY 1998 BO	FY 1999 BA	FY 2000[a] BA	FY 2001[a] BA	FY 2002[b] BA	FY 2003[b] BA	FY 2004[b] BA
Direct							
DOE Effort	2849	2887	3029	3079	2943	2867	2867
Work for Non DOE	474	653	653	653	653	653	653
Total Direct	3323	3540	3683	3732	3596	3520	3520
Total Indirect	3676	3760	3617	3568	3704	3780	3780
Total Personnel	6999	7300	7300	7300	7300	7300	7300

[a]4.0% escalation FY 2000 and 2001.
[b]FY 2002 and beyond in constant FY 2001 dollars.

Table 6.1-3. Funding by Secretarial Officer Resources by major program (in millions of dollars; personnel in FTEs).

Major Program	FY 1998 BO	FY 1999 BA	FY 2000[a] BA	FY 2001[a] BA	FY 2002[b] BA	FY 2003[b] BA	FY 2004[b] BA
Defense Programs							
Operating Costs	509.0	505.1	576.5	634.7	630.0	630.0	630.0
Capital Equipment	9.5	6.7	5.5	5.5	5.5	5.5	5.5
Construction[c]	181.9	308.8	264.4	27.8	30.2	23.0	23.0
Total Cost/Funding[c]	700.4	820.6	846.4	668.0	665.7	658.5	658.5
Direct Personnel	1689	1881	1839	1871	1735	1659	1659
Nonproliferation & National Security							
Operating Costs	74.6	89.6	101.1	106.1	106.1	106.1	106.1
Capital Equipment	1.0	0.7	0.4	0.5	0.5	0.5	0.5
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	75.6	90.3	101.6	106.6	106.6	106.6	106.6
Direct Personnel	204	252	269	296	296	296	296
Office of Intelligence							
Operating Costs	5.6	5.0	5.0	5.0	5.0	5.0	5.0
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	5.6	5.0	5.0	5.0	5.0	5.0	5.0
Direct Personnel	28	18	18	15	15	15	15
Office of Counterintelligence							
Operating Costs	1.6	2.0	3.3	3.8	3.8	3.8	3.8
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	1.6	2.0	3.3	3.8	3.8	3.8	3.8
Direct Personnel	2	9	16	17	17	17	17
Office of Fissile Materials Disposition							
Operating Costs	19.8	26.7	22.0	12.0	12.0	12.0	12.0
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	19.8	26.7	22.0	12.0	12.0	12.0	12.0
Direct Personnel	52	57	46	23	23	23	23
Office of Science							
Operating Costs	45.1	57.7	62.2	68.4	68.5	68.5	68.5
Capital Equipment	2.9	3.7	1.3	0.7	0.8	0.8	0.8
Construction	0.8	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	48.8	61.4	63.5	69.1	69.3	69.3	69.2
Direct Personnel	170	208	317	347	347	347	347
Environmental Restoration & Waste Management							
Operating Costs	46.8	47.1	49.6	49.6	49.6	49.6	49.6
Capital Equipment	3.1	0.7	0.0	0.0	0.0	0.0	0.0
Construction	0.1	3.7	2.0	2.0	0.7	0.0	0.0
Total Cost/Funding	50.0	51.5	51.6	51.6	50.3	49.6	49.6
Direct Personnel	202	215	215	196	196	196	196

Table 6.1-3, continued. Funding by Secretarial Officer Resources by major program (in millions of dollars; personnel in FTEs).

Major Program	FY 1998 BO	FY 1999 BA	FY 2000[a] BA	FY 2001[a] BA	FY 2002[b] BA	FY 2003[b] BA	FY 2004[b] BA
Environmental Safety & Health							
Operating Costs	3.6	3.5	2.8	2.8	2.8	2.8	2.8
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	3.6	3.5	2.8	2.8	2.8	2.8	2.8
Direct Personnel	13	11	10	9	9	9	9
Nuclear Energy							
Operating Costs	8.7	0.5	0.5	0.5	0.5	0.5	0.5
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	8.7	0.5	0.5	0.5	0.5	0.5	0.5
Direct Personnel	21	1	1	1	1	1	1
Fossil Energy							
Operating Costs	1.9	4.5	5.1	4.9	4.9	4.9	4.9
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	1.9	4.5	5.1	4.9	4.9	4.9	4.9
Direct Personnel	6	5	18	16	16	16	16
Energy Efficiency & Renewable Energy							
Operating Costs	3.3	5.7	9.0	11.0	11.0	11.0	11.0
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.8	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	4.1	5.7	9.1	11.0	11.0	11.0	11.0
Direct Personnel	10	17	30	35	35	35	35
Human Resources & Administration							
WM General Administration-Contractual Services							
Operating Costs	0.5	0.5	0.8	0.8	0.8	0.8	0.8
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	0.5	0.5	0.8	0.8	0.8	0.8	0.8
Direct Personnel	3	3	3	3	3	3	3
Policy, Planning & Program Evaluation							
Operating Costs	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	1	0	0	0	0	0	0
Office of Chief Financial Officer							
Operating Costs	60.0	0.0	0.0	0.0	0.0	0.0	0.0
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	60.0	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	178	0	0	0	0	0	0

Table 6.1-3, continued. Funding by Secretarial Officer Resources by major program (in millions of dollars; personnel in FTEs).

Major Program	FY 1998 BO	FY 1999 BA	FY 2000[a] BA	FY 2001[a] BA	FY 2002[b] BA	FY 2003[b] BA	FY 2004[b] BA
Office of Civilian Radioactive Waste Management - DF							
Operating Costs	0.0	0.2	0.0	0.0	0.0	0.0	0.0
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	0	1	0	0	0	0	0
Total DOE Programs							
Operating Costs	780.6	748.1	837.9	899.6	895.0	895.0	895.0
Capital Equipment	16.5	11.8	7.4	6.7	6.8	6.8	6.8
Construction[c]	183.6	312.5	266.4	29.8	30.9	23.0	23.0
Total Cost/Funding[c]	980.7	1072.5	1111.7	936.2	932.7	924.8	924.7
Direct Personnel	2577	2676	2780	2829	2693	2616	2616
Work for Others DOE							
Operating Costs	82.0	74.2	80.4	84.3	84.3	84.3	84.3
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	82.0	74.2	80.4	84.3	84.3	84.3	84.3
Direct Personnel	272	250	250	250	250	250	250
Total Program Funding							
Operating Costs	862.6	822.3	918.3	983.9	979.3	979.3	9979.3
Capital Equipment	16.5	11.8	7.4	6.7	6.8	6.8	6.8
Construction[c]	183.6	312.5	266.4	103.9	95.9	26.6	26.6
Total Cost/Funding[c]	1062.7	1146.7	1192.1	1094.6	1082.0	1012.7	1012.6
Direct Personnel	2849	2926	3029	3079	2943	2866	2866
General Purpose Equipment	7.8	7.8	7.8	7.8	7.8	7.8	7.8
General Plant Projects	8.0	10.1	10.5	5.9	0.3	0.3	0.3
General Purpose Facilities	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Proposed Construction	0.0	0.0	0.0	5.0	16.0	1.5	1.5

[a]4.0% escalation FY 2000 and 2001.
[b]FY 2002 and beyond in constant FY 2001 dollars.
[c]National Ignition Facility construction estimates are TBD and thus are excluded from FY 2001–2004 totals.

Table 6.1-3a. Personnel by Secretarial Officer (personnel in FTEs).

Major Program	FY 1998 BO	FY 1999 BA	FY 2000 BA	FY 2001 BA	FY 2002 BA	FY 2003 BA	FY 2004 BA
Defense Programs							
Operating Costs	1289	1436	1539	1621	1601	1601	1601
Capital Equipment	1	0	0	0	0	0	0
Construction	399	418	300	250	134	58	58
Total Defense Programs	1689	1854	1839	1871	1735	1659	1659
Nonproliferation & National Security							
Operating Costs	204	240	269	296	296	296	296
Capital Equipment	0	0	0	0	0	0	0
Construction	0	0	0	0	0	0	0
Total Nonproliferation	204	240	269	296	296	296	296
Office of Intelligence							
Operating Costs	28	18	18	15	15	15	15
Capital Equipment	0	0	0	0	0	0	0
Construction	0	0	0	0	0	0	0
Total Office of Intelligence	28	18	18	15	15	15	15
Office of Counterintelligence							
Operating Costs	2	9	16	17	17	17	17
Capital Equipment	0	0	0	0	0	0	0
Construction	0	0	0	0	0	0	0
Total Office of Counterintelligence	2	9	16	17	17	17	17
Office of Fissile Mat. Disp.							
Operating Costs	52	57	46	23	23	23	23
Capital Equipment	0	0	0	0	0	0	0
Construction	0	0	0	0	0	0	0
Total Office of Fissile Materials	52	57	46	23	23	23	23
Office of Science							
Operating Costs	161	207	317	347	347	347	347
Capital Equipment	3	1	0	0	0	0	0
Construction	7	0	0	0	0	0	0
Total Office of Science	170	208	317	347	347	347	347
Environmental Restoration & Waste Management							
Operating Costs	189	209	210	195	195	195	196
Capital Equipment	11	4	4	0	0	0	0
Construction	1	2	1	1	1	1	0
Total Env. Rest./W Mgmt	202	215	215	196	196	196	196
Total Environmental Safety & Health							
Operating Costs	13	11	10	9	9	9	9
Capital Equipment	0	0	0	0	0	0	0
Construction	0	0	0	0	0	0	0
Total Env. Safety & Health	13	11	10	9	9	9	9

Table 6.1-3a, continued. Personnel by Secretarial Officer (personnel in FTEs).

Major Program	FY 1998 BO	FY 1999 BA	FY 2000 BA	FY 2001 BA	FY 2002 BA	FY 2003 BA	FY 2004 BA
Nuclear Energy							
Operating Costs	21	1	1	1	1	1	1
Capital Equipment	0	0	0	0	0	0	0
Construction	0	0	0	0	0	0	0
Total Nuclear Energy	21	1	1	1	1	1	1
Fossil Energy							
Operating Costs	6	5	18	16	16	16	16
Capital Equipment	0	0	0	0	0	0	0
Construction	0	0	0	0	0	0	0
Total Fossil Energy	6	5	18	16	16	16	16
Energy Efficiency & Renewable Energy							
Operating Costs	9	17	30	35	35	35	35
Capital Equipment	0	0	0	0	0	0	0
Construction	1	0	0	0	0	0	0
Total Energy Efficiency & Renewable Energy	10	17	30	35	35	35	35
Human Resources & Administration							
Operating Costs	3	3	3	3	3	3	3
Capital Equipment	0	0	0	0	0	0	0
Construction	0	0	0	0	0	0	0
Total Human Resources & Admin	3	3	3	3	3	3	3
Policy, Planning & Program Evaluation							
Operating Costs	0	0	0	0	0	0	0
Capital Equipment	0	0	0	0	0	0	0
Construction	0	0	0	0	0	0	0
Total Policy, Planning	0	0	0	0	0	0	0
Office of Chief Financial Officer							
Operating Costs	178	0	0	0	0	0	0
Capital Equipment	0	0	0	0	0	0	0
Construction	0	0	0	0	0	0	0
Total Office of Chief Financial Officer	178	0	0	0	0	0	0
Office of Civilian Radioactive Waste Management							
Operating Costs	0	0	0	0	0	0	0
Capital Equipment	0	0	0	0	0	0	0
Construction	0	0	0	0	0	0	0
Total Civilian Radioactive Waste	0	0	0	0	0	0	0
Other DOE Facilities/Field Offices							
Operating Costs	272	250	250	250	250	250	250
Capital Equipment	0	0	0	0	0	0	0
Construction	0	0	0	0	0	0	0
Total Other DOE Facilities	272	250	250	250	250	250	250

Table 6.1-3a, continued. Personnel by Secretarial Officer (personnel in FTEs).

Major Program	FY 1998 BO	FY 1999 BA	FY 2000 BA	FY 2001 BA	FY 2002 BA	FY 2003 BA	FY 2004 BA
Total DOE Programs							
Operating Costs	2426	2462	2724	2827	2807	2807	2809
Capital Equipment	15	5	4	0	0	0	0
Construction	408	420	301	251	135	59	58
Total DOE Programs - FTEs	2849	2887	3029	3079	2943	2867	2867
Work for Others (Non-DOE)							
Operating Costs	474	653	653	653	653	653	653
Capital Equipment	0	0	0	0	0	0	0
Construction	0	0	0	0	0	0	0
Total Work for Others (Non-DOE)	474	653	653	653	653	653	653
Total Program Effort							
Operating Costs	2900	3116	3378	3481	3461	3461	3462
Capital Equipment	15	5	4	0	0	0	0
Construction	408	420	301	251	135	59	58
Total FTEs	3323	3540	3683	3732	3596	3520	3520
General Purpose Equipment	0	0	0	0	0	0	0
General Plant Projects	0	0	0	0	0	0	0
General Purpose Facilities	0	0	0	0	0	0	0
Proposed Construction	N/A	N/A	N/A	TBD	TBD	TBD	TBD
Total Direct Personnel	3323	3540	3683	3732	3596	3520	3520
Total Indirect Personnel	3676	3760	3617	3568	3704	3780	3780
Total Laboratory Personnel	6999	7300	7300	7300	7300	7300	7300

Table 6.1-4. Defense Programs detailed resource breakout by program element (in millions of dollars; personnel in full-time equivalents).

Major Program	FY 1998 BO	FY 1999 BA	FY 2000[a] BA	FY 2001[a] BA	FY 2002[b] BA	FY 2003[b] BA	FY 2004[b] BA
Core Stockpile and Stewardship-DP0101							
Operating Costs	328.8	353.3	421.4	450.0	450.0	450.0	450.0
Capital Equipment	2.9	6.2	5.0	5.0	5.0	5.0	5.0
Construction	22.0	19.7	16.3	27.8	30.2	23.0	23.0
Total Cost/Funding	353.7	379.2	442.7	482.8	482.8	482.8	482.8
Direct Personnel	868	1054	1156	1189	1189	1189	1189
Inertial Confinement Fusion-DP02							
Operating Costs	84.4	101.0	107.0	134.5	134.5	134.5	134.5
Capital Equipment	5.9	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	90.3	101.0	107.0	134.5	134.5	134.5	134.5
Direct Personnel	239	227	247	297	297	297	297
National Ignition Facility-DP0213							
Operating Costs	48.2	6.8	5.9	5.9	1.2	1.2	1.2
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction[c]	157.2	284.2	248.1	TBD	TBD	TBD	TBD
Total Cost/Funding[c]	205.4	291.0	254.0	5.9	1.2	1.2	1.2
Direct Personnel	388	409	277	277	91	15	15
Technology Transfer and Education-DP03							
Operating Costs	6.2	2.9	2.5	3.0	3.0	3.0	3.0
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	6.2	2.9	2.5	3.0	3.0	3.0	3.0
Direct Personnel	25	16	13	14	14	14	14
Weapons Stockpile Management-DP04							
Operating Costs	37.2	39.3	39.6	41.1	41.1	41.1	41.1
Capital Equipment	0.7	0.5	0.5	0.5	0.5	0.5	0.5
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	37.9	39.8	40.1	41.6	41.6	41.6	41.6
Direct Personnel	138	143	145	143	143	143	143
Program Direction-DP05							
Operating Costs	4.2	1.8	0.1	0.2	0.2	0.2	0.2
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	4.2	1.8	0.1	0.2	0.2	0.2	0.2
Direct Personnel	9	5	1	1	1	1	1
DARHT Construction							
Operating Costs	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	2.7	4.9	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	2.7	4.9	0.0	0.0	0.0	0.0	0.0
Direct Personnel	22	27	0	0	0	0	0

Table 6.1-4, continued. Defense Programs detailed resource breakout by program element (in millions of dollars; personnel in full-time equivalents).

Major Program	FY 1998 BO	FY 1999 BA	FY 2000[a] BA	FY 2001[a] BA	FY 2002[b] BA	FY 2003[b] BA	FY 2004[b] BA
Total Defense Programs							
Operating Costs	509.0	505.1	576.5	634.7	630.0	630.0	630.0
Capital Equipment	9.5	6.7	5.5	5.5	5.5	5.5	5.5
Construction[c]	181.9	308.8	264.4	101.9	95.2	26.6	26.6
Total Cost/Funding [c]	700.4	820.6	846.4	668.0	665.7	658.5	658.5
Direct Personnel	1689	1881	1839	1871	1735	1659	1659
General Purpose Equipment (GPE)	4.6	4.6	4.6	4.6	4.6	4.6	4.6
General Plant Projects (GPP)	6.7	8.5	4.9	0.3	0.3	0.3	0.3
General Purpose Facilities	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Proposed Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0

[a]4.0% escalation FY 2000 and 2001.
[b]FY 2002 and beyond in constant FY 2001 dollars.
[c]National Ignition Facility construction estimates are TBD and thus are excluded from FY 2001–2004 totals.

Table 6.1-5. Nonproliferation and National Security detailed resource breakout by program element (in millions of dollars; personnel in full-time equivalent).

Major Program	FY 1998 BO	FY 1999 BA	FY 2000[a] BA	FY 2001[a] BA	FY 2002[b] BA	FY 2003[b] BA	FY 2004[b] BA
Program Direction-CD30							
Operating Costs	0.0	5.5	6.9	7.9	7.9	7.9	7.9
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	0.0	5.5	6.9	7.9	7.9	7.9	7.9
Direct Personnel	0	20	22	26	26	26	26
Nonprolif & Verif Res & Develop-GC00							
Operating Costs	37.7	38.1	44.6	51.8	51.8	51.8	51.8
Capital Equipment	0.9	0.4	0.4	0.4	0.4	0.4	0.4
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	38.6	38.5	45.0	52.2	52.2	52.2	52.2
Direct Personnel	124	137	149	160	160	160	160
Arms Export Control & Nonproliferation-GJ							
Operating Costs	29.8	39.1	40.3	40.4	40.4	40.4	40.4
Capital Equipment	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	29.9	39.1	40.3	40.4	40.4	40.4	40.4
Direct Personnel	58	69	78	84	84	84	84
Emergency Management Program-ND							
Operating Costs	0.8	0.8	0.9	0.9	0.9	0.9	0.9
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	0.8	0.8	0.9	0.9	0.9	0.9	0.9
Direct Personnel	1	1	1	2	2	2	2
Program Direction-NN01							
Operating Costs	0.3	0.0	0.0	0.0	0.0	0.0	0.0
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	0.3	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	0	0	0	0	0	0	0
Classification Resources-GD03							
Operating Costs	0.3	0.3	0.4	0.3	0.3	0.3	0.3
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	0.3	0.3	0.4	0.3	0.3	0.3	0.3
Direct Personnel	1	1	1	1	1	1	1
Operations and Support-GD05							
Operating Costs	0.8	0.8	1.2	0.7	0.7	0.7	0.7
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	0.8	0.8	1.2	0.7	0.7	0.7	0.6
Direct Personnel	3	2	3	3	3	3	3

Table 6.1-5, continued. Nonproliferation and National Security detailed resource breakout by program element (in millions of dollars; personnel in full-time equivalent).

Major Program	FY 1998 BO	FY 1999 BA	FY 2000[a] BA	FY 2001[a] BA	FY 2002[b] BA	FY 2003[b] BA	FY 2004[b] BA
Technology & Systems Development-GD06							
Operating Costs	4.7	4.9	6.8	4.1	4.1	4.1	4.1
Capital Equipment	0.0	0.2	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	4.7	5.2	6.8	4.2	4.2	4.2	4.2
Direct Personnel	17	22	17	20	20	20	20
Related Security investigations Activity-GH03							
Operating Costs	0.2	0.0	0.0	0.0	0.0	0.0	0.0
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	0.2	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	1	0	0	0	0	0	0
Total Nonproliferation & National Security							
Operating Costs	74.6	89.6	101.1	106.1	106.1	106.1	106.1
Capital Equipment	1.0	0.7	0.4	0.5	0.5	0.5	0.5
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	75.6	90.3	101.6	106.6	106.6	106.6	106.6
Direct Personnel	204	252	269	296	296	296	296
Total Projected Funding	0.7	0.7	0.7	0.7	0.7	0.7	0.7
General Purpose Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0
General Plant Projects	0.0	0.0	0.0	0.0	0.0	0.0	0.0
General Purpose Facilities	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Proposed Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0

[a]4.0% escalation FY 2000 and 2001.
[b]FY 2002 and beyond in constant FY 2001 dollars.

Table 6.1-5a. Intelligence detailed resource breakout by program element (in millions of dollars; personnel in full-time equivalent).

Major Program	FY 1998 BO	FY 1999 BA	FY 2000[a] BA	FY 2001[a] BA	FY 2002[b] BA	FY 2003[b] BA	FY 2004[b] BA
Intelligence-IN							
Operating Costs	0.0	5.0	5.0	5.0	5.0	5.0	5.0
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	0.0	5.0	5.0	5.0	5.0	5.0	5.0
Direct Personnel	0	18	18	15	15	15	15
Analytical Support-NT01							
Operating Costs	5.4	0.0	0.0	0.0	0.0	0.0	0.0
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	5.4	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	28	0	0	0	0	0	0
Threat Assessment-NT02	0.2	0.0	0.0	0.0	0.0	0.0	0.0
Operating Costs	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.2	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	0	0	0	0	0	0	0
Direct Personnel							
Total Office of Intelligence	5.6	5.0	5.0	5.0	5.0	5.0	5.0
Operating Costs	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	5.6	5.0	5.0	5.0	5.0	5.0	5.0
Total Cost/Funding	28	18	18	15	15	15	15
Direct Personnel							
General Purpose Equipment	1.4	1.4	1.4	1.4	1.4	1.4	1.4
General Plant Projects	0.0	0.0	0.0	0.0	0.0	0.0	0.0
General Purpose Facilities	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Proposed Construction	0.0	0.0	0.0	5.0	16.0	1.5	1.5

[a]4.0% escalation FY 2000 and 2001.
[b]FY 2002 and beyond in constant FY 2001 dollars.

Table 6.1-5b. Counterintelligence detailed resource breakout by program element (in millions of dollars; personnel in full-time equivalent).

Major Program	FY 1998 BO	FY 1999 BA	FY 2000[a] BA	FY 2001[a] BA	FY 2002[b] BA	FY 2003[b] BA	FY 2004[b] BA
Counterintelligence-NT03							
Operating Costs	1.6	0.0	0.0	0.0	0.0	0.0	0.0
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	1.6	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	2	0	0	0	0	0	0
Counterintelligence-CN							
Operating Costs	0.0	2.0	3.0	3.8	3.8	3.8	3.8
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	0.0	2.0	3.0	3.8	3.8	3.8	3.8
Direct Personnel	0	9	16	17	17	17	17
Total Counterintelligence							
Operating Costs	1.6	2.0	3.0	3.8	3.8	3.8	3.8
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	1.6	2.0	3.3	3.8	3.8	3.8	3.8
Direct Personnel	2	9	16	17	17	17	17

[a]4.0% escalation FY 2000 and 2001.
[b]FY 2002 and beyond in constant FY 2001 dollars.

Table 6.1-6. Fissile Materials Disposition detailed resource breakout by program element (in millions of dollars; personnel in full-time equivalent).

Major Program	FY 1998 BO	FY 1999 BA	FY 2000[a] BA	FY 2001[a] BA	FY 2002[b] BA	FY 2003[b] BA	FY 2004[b] BA
Storage and Disposition Options-GA01							
Operating Costs	19.8	26.7	22.0	12.0	12.0	12.0	12.0
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	19.8	26.7	22.0	12.0	12.0	12.0	12.0
Direct Personnel	52	57	46	23	23	23	23
Total Fissile Materials Disposition							
Operating Costs	19.8	26.7	22.0	12.0	12.0	12.0	12.0
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	19.8	26.7	22.0	12.0	12.0	12.0	12.0
Direct Personnel	52	57	46	23	23	23	23
General Purpose Equipment	0.2	0.2	0.2	0.2	0.2	0.2	0.2
General Plant Projects	0.0	0.0	0.0	0.0	0.0	0.0	0.0
General Purpose Facilities	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Proposed Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0

[a]4.0% escalation FY 2000 and 2001.
[b]FY 2002 and beyond in constant FY 2001 dollars.

Table 6.1-7. Science detailed resource breakout by program element (in millions of dollars; personnel in full-time equivalent).

Major Program	FY 1998 BO	FY 1999 BA	FY 2000[a] BA	FY 2001[a] BA	FY 2002[b] BA	FY 2003[b] BA	FY 2004[b] BA
Life Sciences-KP11							
Operating Costs	19.6	27.1	22.3	24.5	24.5	24.5	24.5
Capital Equipment	1.8	2.9	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	21.4	30.0	22.3	24.5	24.5	24.5	24.5
Direct Personnel	70	78	115	133	133	133	133
Environmental Processes-KP12							
Operating Costs	5.9	7.3	13.8	17.2	17.2	17.2	17.2
Capital Equipment	0.0	0.2	0.7	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	5.9	7.5	14.5	17.2	17.2	17.2	17.2
Direct Personnel	31	61	90	103	103	103	103
Medical Applications & Measurement Sci-KP14							
Operating Costs	0.0	0.1	0.1	0.1	0.1	0.1	0.1
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	0.0	0.1	0.1	0.1	0.0	0.0	0.0
Direct Personnel	0	0	0	0	0	0	0
Fusion Energy Sciences-AT00							
Operating Costs	9.8	11.3	11.7	9.2	9.2	9.2	9.2
Capital Equipment	0.0	0.0	0.0	0.1	0.1	0.1	0.1
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	9.8	11.3	11.7	9.3	9.3	9.3	9.3
Direct Personnel	37	41	49	39	39	39	39
Basic Energy Sciences-KC02							
Operating Costs	3.6	3.6	3.7	4.4	4.4	4.4	4.4
Capital Equipment	0.3	0.3	0.3	0.3	0.4	0.4	0.4
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	3.9	3.9	4.0	4.7	4.8	4.8	4.8
Direct Personnel	8	9	25	27	27	27	27
Chemical Sciences-KC03							
Operating Costs	0.8	1.0	1.9	2.2	2.2	2.2	2.2
Capital Equipment	0.1	0.1	0.2	0.2	0.2	0.2	0.2
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	0.9	1.1	2.1	2.4	2.4	2.4	2.4
Direct Personnel	2	2	4	5	5	5	5
Engineering and Geosciences-KC04							
Operating Costs	1.6	1.5	1.4	1.4	1.5	1.5	1.5
Capital Equipment	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	1.7	1.6	1.5	1.5	1.6	1.6	1.6
Direct Personnel	3	4	4	4	4	4	4

Table 6.1-7, continued. Science detailed resource breakout by program element (in millions of dollars; personnel in full-time equivalent).

Major Program	FY 1998 BO	FY 1999 BA	FY 2000[a] BA	FY 2001[a] BA	FY 2002[b] BA	FY 2003[b] BA	FY 2004[b] BA
Math, Information and Comp Sci-KJ01							
Operating Costs	2.2	3.2	4.3	6.0	6.0	6.0	6.0
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	2.2	3.2	4.3	6.0	6.0	6.0	6.0
Direct Personnel	8	10	13	17	17	17	17
Adv. Energy Projects-KJ03							
Operating Costs	0.2	0.0	0.0	0.0	0.0	0.0	0.0
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	0.2	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	0	0	0	0	0	0	0
Facility Operations-KA02							
Operating Costs	0.2	0.3	0.0	0.0	0.0	0.0	0.0
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.8	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	1.0	0.3	0.0	0.0	0.0	0.0	0.0
Direct Personnel	3	0	0	0	0	0	0
High-Energy Technology-KA04							
Operating Costs	0.6	1.2	1.7	2.2	2.2	2.2	2.2
Capital Equipment	0.5	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	1.1	1.2	1.7	2.2	2.2	2.2	2.2
Direct Personnel	8	1	9	11	11	11	11
Heavy Ion Physics-KB02							
Operating Costs	0.2	0.4	0.5	0.4	0.4	0.4	0.4
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	0.2	0.4	0.5	0.4	0.4	0.4	0.4
Direct Personnel	0	0	4	4	4	4	4
Low-Energy Physics-KB04							
Operating Costs	0.4	0.7	0.8	0.8	0.8	0.8	0.8
Capital Equipment	0.0	0.1	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	0.4	0.8	0.8	0.8	0.8	0.8	0.8
Direct Personnel	1	1	5	5	5	5	5
Total Science							
Operating Costs	45.1	57.7	62.2	68.4	68.5	68.5	68.5
Capital Equipment	2.9	3.7	1.3	0.7	0.8	0.8	0.8
Construction	0.8	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	48.8	61.4	63.5	69.1	69.3	69.3	69.2
Direct Personnel	170	208	317	347	347	347	347

Table 6.1-7, continued. Science detailed resource breakout by program element (in millions of dollars; personnel in full-time equivalent).

Major Program	FY 1998 BO	FY 1999 BA	FY 2000[a] BA	FY 2001[a] BA	FY 2002[b] BA	FY 2003[b] BA	FY 2004[b] BA
General Purpose Equipment	0.5	0.5	0.5	0.5	0.5	0.5	0.5
General Plant Projects	0.7	0.3	3.5	4.0	0.0	0.0	0.0
Proposed Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0

[a]4.0% escalation FY 2000 and 2001.
[b]FY 2002 and beyond in constant FY 2001 dollars.

Table 6.1-8. Environmental Restoration and Waste Management detailed resource breakout by program element (in millions of dollars; personnel in full-time equivalent).

Major Program	FY 1998 BO	FY 1999 BA	FY 2000[a] BA	FY 2001[a] BA	FY 2002[b] BA	FY 2003[b] BA	FY 2004[b] BA
Program Direction (Defense)-EW02							
Operating Costs	0.0	0.9	0.9	0.9	0.9	0.9	0.9
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	0.0	0.9	0.9	0.9	0.9	0.9	0.9
Direct Personnel	0	4	4	1	1	1	1
Program Direction (Defense)-EW04							
Operating Costs	0.0	40.5	45.9	46.7	46.7	46.7	46.7
Capital Equipment	3.1	0.7	0.0	0.0	0.0	0.0	0.0
Construction	0.0	3.7	2.0	2.0	0.7	0.0	0.0
Total Cost/Funding	0.0	44.9	47.9	48.7	47.4	46.7	46.7
Direct Personnel	0	187	202	189	189	189	189
Program Direction (Defense)-EW10							
Operating Costs	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	0	0	0	0	0	0	0
Environmental Restoration-EW20							
Operating Costs	21.3	0.0	0.0	0.0	0.0	0.0	0.0
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	21.3	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	97	0	0	0	0	0	0
Waste Management (Defense)-EW31							
Operating Costs	18.2	0.0	0.0	0.0	0.0	0.0	0.0
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	18.3	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	84	0	0	0	0	0	0
Technology Development-EW40							
Operating Costs	1.7	4.1	1.2	0.4	0.4	0.4	0.4
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	1.7	4.1	1.2	0.4	0.4	0.4	0.4
Direct Personnel	1	18	3	0	0	0	0

Table 6.1-8, continued. Environmental Restoration and Waste Management detailed resource breakout by program element (in millions of dollars; personnel in full-time equivalent).

Major Program	FY 1998 BO	FY 1999 BA	FY 2000[a] BA	FY 2001[a] BA	FY 2002[b] BA	FY 2003[b] BA	FY 2004[b] BA
Environmental Management and Waste Mgmt - Def							
Environmental Management Science Program-EW45							
Operating Costs	2.5	0.0	0.0	0.0	0.0	0.0	0.0
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	2.5	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	1	0	0	0	0	0	0
Facility Transition & Management-EW70							
Operating Costs	1.3	0.0	0.0	0.0	0.0	0.0	0.0
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	1.3	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	1	0	0	0	0	0	0
Environmental Restoration & Waste Mgmt(Non-D)							
Waste Management(Non-D)–EX02							
Operating Costs	0.0	1.6	1.6	1.6	1.6	1.6	1.6
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	0.0	1.6	1.6	1.6	1.6	1.6	1.6
Direct Personnel	0	6	6	6	6	6	6
Nuclear Material & Facility Stabilization-EX70							
Operating Costs	1.7	0.0	0.0	0.0	0.0	0.0	0.0
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	1.7	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	7	0	0	0	0	0	0
Total Environmental Restoration & Waste Management							
Operating Costs	46.8	47.1	49.6	49.6	49.6	49.6	49.6
Capital Equipment	3.1	0.7	0.0	0.0	0.0	0.0	0.0
Construction	0.1	3.7	2.0	2.0	0.7	0.0	0.0
Total Cost/Funding	50.0	51.5	51.6	51.6	50.3	49.6	49.6
Direct Personnel	202	215	215	196	196	196	196
General Purpose Equipment	0.5	0.5	0.5	0.5	0.5	0.5	0.5
General Plant Projects	0.5	1.3	2.0	1.5	0.0	0.0	0.0
General Purpose Facilities	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Proposed Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0

[a]4.0% escalation FY 2000 and 2001.
[b]FY 2002 and beyond in constant FY 2001 dollars.

Table 6.1-9. Environmental Safety and Health detailed resource breakout by program element (in millions of dollars; personnel in full-time equivalent).

Major Program	FY 1998 BO	FY 1999 BA	FY 2000[a] BA	FY 2001[a] BA	FY 2002[b] BA	FY 2003[b] BA	FY 2004[b] BA
Line Mgmnt Support-HC11							
Operating Costs	0.8	0.6	0.1	0.1	0.1	0.1	0.1
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	0.8	0.6	0.1	0.1	0.1	0.1	0.1
Direct Personnel	3	2	1	0	0	0	0
Health Studies-HD20							
Operating Costs	2.6	2.9	2.7	2.7	2.7	2.7	2.7
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	2.6	2.9	2.7	2.7	2.7	2.7	2.7
Direct Personnel	10	9	9	9	9	9	9
Health Studies-HD40							
Operating Costs	0.2	0.0	0.0	0.0	0.0	0.0	0.0
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	0.2	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	0	0	0	0	0	0	0
Total Env. Safety & Health							
Operating Costs	3.6	3.5	2.8	2.8	2.8	2.8	2.8
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	3.6	3.5	2.8	2.8	2.8	2.8	2.8
Direct Personnel	13	11	10	9	9	9	9

[a]4.0% escalation FY 2000 and 2001.
[b]FY 2002 and beyond in constant FY 2001 dollars.

Table 6.1-10. Nuclear Energy detailed resource breakout by program element (in millions of dollars; personnel in full-time equivalent).

Major Program	FY 1998 BO	FY 1999 BA	FY 2000[a] BA	FY 2001[a] BA	FY 2002[b] BA	FY 2003[b] BA	FY 2004[b] BA
Naval Reactors Development-AJ05							
Operating Costs	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Direct Personnel	0	0	0	0	0	0	0
Atomic Vapor Laser Isotope Separation-CD1008							
Operating Costs	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	0	0	0	0	0	0	0
Program Management Services-CD1012							
Operating Costs	0.9	0.2	0.2	0.2	0.2	0.2	0.2
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	0.9	0.2	0.2	0.2	0.2	0.2	0.2
Direct Personnel	4	1	1	1	1	1	1
Transparency Measures-CD1013							
Operating Costs	6.8	0.0	0.0	0.0	0.0	0.0	0.0
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	6.8	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	10	0	0	0	0	0	0
Depleted Uran Hexaflour Cyl & Mntc-CD1015							
Operating Costs	0.6	0.0	0.0	0.0	0.0	0.0	0.0
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	0.6	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	7	0	0	0	0	0	0
Total Nuclear Energy							
Operating Costs	8.7	0.5	0.5	0.5	0.5	0.5	0.5
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	8.7	0.5	0.5	0.5	0.5	0.5	0.5
Direct Personnel	21	1	1	1	1	1	1

[a]4.0% escalation FY 2000 and 2001.
[b]FY 2002 and beyond in constant FY 2001 dollars.

Table 6.1-11. Fossil Energy detailed resource breakout by program element (in millions of dollars; personnel in full-time equivalent).

Major Program	FY 1998 BO	FY 1999 BA	FY 2000[a] BA	FY 2001[a] BA	FY 2002[b] BA	FY 2003[b] BA	FY 2004[b] BA
Natural Gas Research-AB05							
Operating Costs	0.3	1.0	1.6	1.2	1.2	1.2	1.2
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	0.3	1.0	1.6	1.2	1.2	1.2	1.2
Direct Personnel	1	2	6	4	4	4	4
Petroleum Research-AC10							
Exploration & Production Supporting Res.-AC1005							
Operating Costs	1.2	3.2	3.5	3.7	3.7	3.7	3.7
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	1.2	3.2	3.5	3.7	3.7	3.7	3.7
Direct Personnel	5	2	12	12	12	12	12
Exploration & Production Supporting Res.-AC1015							
Operating Costs	0.4	0.2	0.0	0.0	0.0	0.0	0.0
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	0.4	0.2	0.0	0.0	0.0	0.0	0.0
Direct Personnel	1	1	0	0	0	0	0
Processing Research 7 Downstream Ops.-AC1020							
Operating Costs	0.0	0.1	0.0	0.0	0.0	0.0	0.0
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	0.0	0.1	0.0	0.0	0.0	0.0	0.0
Direct Personnel	0	0	0	0	0	0	0
Total Fossil Energy							
Operating Costs	1.9	4.5	5.1	4.9	4.9	4.9	4.9
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	1.9	4.5	5.1	4.9	4.9	4.9	4.9
Direct Personnel	6	5	18	16	16	16	16

[a]4.0% escalation FY 2000 and 2001.
[b]FY 2002 and beyond in constant FY 2001 dollars.

Table 6.1-12. Energy Efficiency and Renewable Energy detailed resource breakout by program element (in millions of dollars; personnel in full-time equivalent).

Major Program	FY 1998 BO	FY 1999 BA	FY 2000[a] BA	FY 2001[a] BA	FY 2002[b] BA	FY 2003[b] BA	FY 2004[b] BA
Solar and Renewable Resource Technologies-EB00							
Operating Costs	0.0	1.7	1.8	4.6	4.6	4.6	4.6
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	0.0	1.7	1.8	4.6	4.6	4.6	4.6
Direct Personnel	0	3	7	15	15	15	15
Hydrogen Research R&D-EB42							
Operating Costs	0.7	0.0	0.0	0.0	0.0	0.0	0.0
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	0.7	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	2.3	0.0	0.0	0.0	0.0	0.0	0.0
Industry Sector-Total-ED18							
Operating Costs	0.2	0.2	0.2	0.0	0.0	0.0	0.0
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	0.2	0.2	0.2	0.0	0.0	0.0	0.0
Direct Personnel	1	1	1	0	0	0	0
Transportation Sector-EE00							
Operating Costs	2.4	3.8	7.0	6.4	6.4	6.4	6.4
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	2.4	3.8	7.0	6.4	6.4	6.4	6.4
Direct Personnel	6	13	23	20	20	20	20
In-House Energy Management-WB00							
Operating Costs	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	1	0	0	0	0	0	0
Total Energy Efficiency & Renewable Energy							
Operating Costs	3.3	5.7	9.0	11.0	11.0	11.0	11.0
Capital Equipment	0.0	0.0	0.1	0.0	0.0	0.0	0.0
Construction	0.8	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	4.1	5.7	9.1	11.0	11.0	11.0	11.0
Direct Personnel	10	17	30	35	35	35	35

[a]4.0% escalation FY 2000 and 2001.
[b]FY 2002 and beyond in constant FY 2001 dollars.

Table 6.1-13. Human Resources and Administration detailed resource breakout by program element (in millions of dollars; personnel in full-time equivalent).

Major Program	FY 1998 BO	FY 1999 BA	FY 2000[a] BA	FY 2001[a] BA	FY 2002[b] BA	FY 2003[b] BA	FY 2004[b] BA
Human Resource & Admin-WM10							
Operating Costs	0.5	0.5	0.8	0.8	0.8	0.8	0.8
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	0.5	0.5	0.8	0.8	0.8	0.8	0.8
Direct Personnel	3	3	3	3	3	3	3

[a]4.0% escalation FY 2000 and 2001.
[b]FY 2002 and beyond in constant FY 2001 dollars.

Table 6.1-14. Policy, Planning, and Program detailed resource breakout by program element (in millions of dollars; personnel in full-time equivalent).

Major Program	FY 1998 BO	FY 1999 BA	FY 2000[a] BA	FY 2001[a] BA	FY 2002[b] BA	FY 2003[b] BA	FY 2004[b] BA
Policy, Planning & Program Analysis-PE							
Operating Costs	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	1	0	0	0	0	0	0

[a]4.0% escalation FY 2000 and 2001.
[b]FY 2002 and beyond in constant FY 2001 dollars.

Table 6.1-15. Office of Chief Financial Officer detailed resource breakout by program element (in millions of dollars; personnel in full-time equivalent).

Major Program	FY 1998 BO	FY 1999 BA	FY 2000[a] BA	FY 2001[a] BA	FY 2002[b] BA	FY 2003[b] BA	FY 2004[b] BA
Office of Chief Financial Officer - HG00 (AVLIS)							
Operating Costs	60.0	0.0	0.0	0.0	0.0	0.0	0.0
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	60.0	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	178	0	0	0	0	0	0
General Purpose Equipment	0.6	0.6	0.6	0.6	0.6	0.6	0.6
General Plant Projects	0.0	0.0	0.0	0.0	0.0	0.0	0.0
General Purpose Facilities	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Proposed Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0

[a]4.0% escalation FY 2001 and 2001.
[b]FY 2002 and beyond in constant FY 2001 dollars.

Table 6.1-16. Office of Civilian Radioactive Waste Management detailed resource breakout by program element (in millions of dollars; personnel in full-time equivalent).

Major Program	FY 1998 BO	FY 1999 BA	FY 2000[a] BA	FY 2001[a] BA	FY 2002[b] BA	FY 2003[b] BA	FY 2004[b] BA
Civilian Radioactive Waste Management - DF							
Operating Costs	0.0	0.2	0.0	0.0	0.0	0.0	0.0
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	0.0	0.2	0.0	0.0	0.0	0.0	0.0
Direct Personnel	0	1	0	0	0	0	0

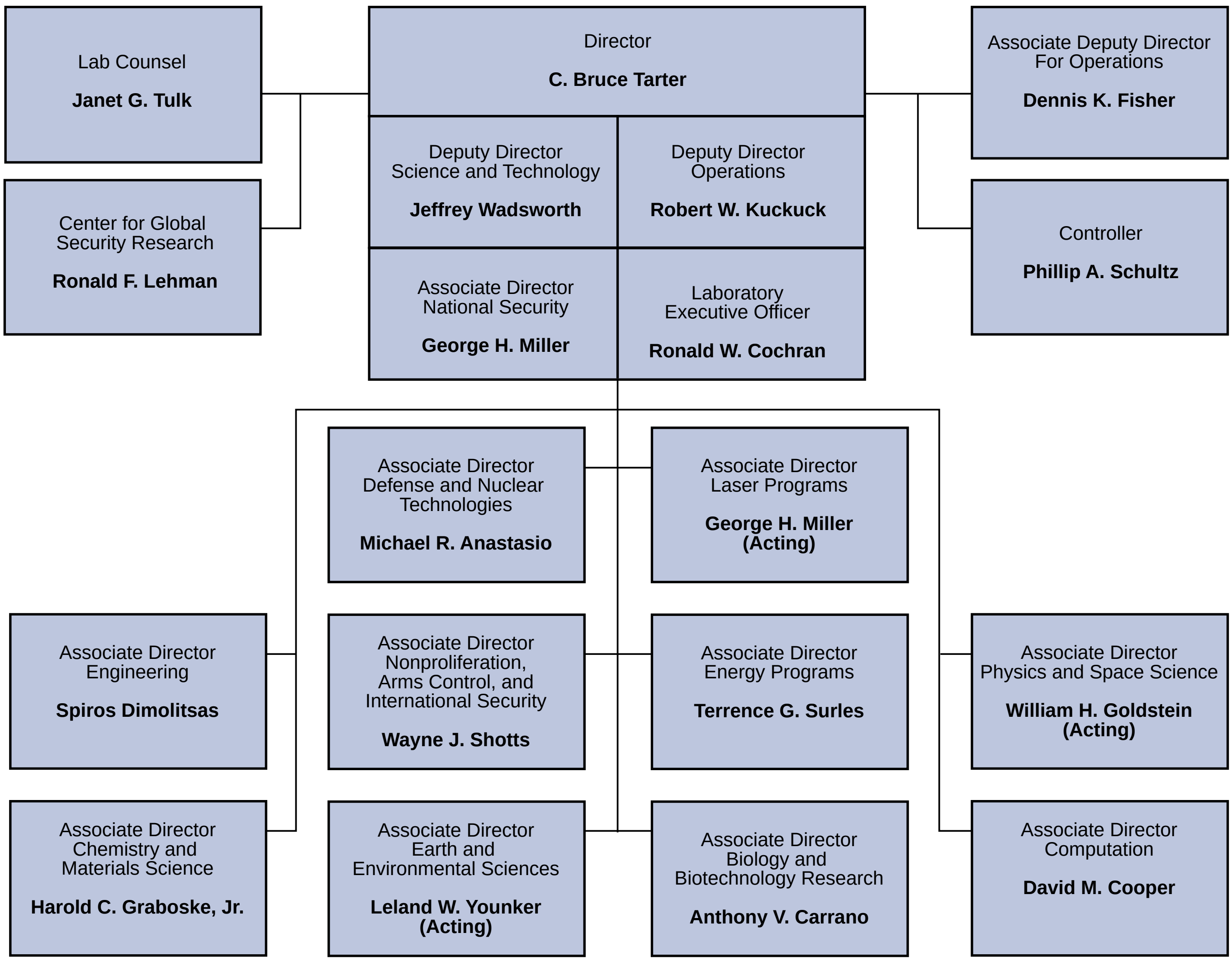
[a]4.0% Escalation FY 2000 and 2001.
[b]FY 2002 and beyond in constant FY 2001 dollars.

Table 6.1-17. Other DOE detailed resource breakout by program element (in millions of dollars; personnel in full-time equivalent).

Major Program	FY 1998 BO	FY 1999 BA	FY 2000[a] BA	FY 2001[a] BA	FY 2002[b] BA	FY 2003[b] BA	FY 2004[b] BA
Work for DOE Integrated Contractors							
Operating Costs	31.1	27.8	30.7	30.6	30.6	30.6	30.6
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	31.1	27.8	30.7	30.6	30.6	30.6	30.6
Direct Personnel	103	95	95	95	95	95	95
Work for Other DOE Installations							
Operating Costs	50.9	46.4	49.7	53.7	53.7	53.7	53.7
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	50.9	46.4	49.7	53.7	53.7	53.7	53.7
Direct Personnel	169	155	155	155	155	155	155
Total Other DOE							
Operating Costs	82.0	74.2	80.4	84.3	84.3	84.3	84.3
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	82.0	74.2	80.4	84.3	84.3	84.3	84.3
Direct Personnel	272	250	250	250	250	250	250

[a]4.0% escalation FY 2000 and 2001.
[b]FY 2002 and beyond in constant FY 2001 dollars.

6.2 Organization chart



6.3 Publications and Internet Addresses

General information about the Laboratory's work may be found electronically on the World Wide Web through the Laboratory's home page at http://www.llnl.gov. Other references called out in this Institutional Plan are shown below.

Please direct requests for hard copies of Livermore publications to:
Ellen Bradley
Off-Site Requests Coordinator
Lawrence Livermore National Laboratory
P.O. Box 808, L-658
Livermore, CA 94551
Phone 510-422-5820

6.3.1 Referenced Publications

Science & Technology Review, Lawrence Livermore National Laboratory, Livermore, CA, UCRL-52000; published 10 times per year beginning July 1995.

Creating the Laboratory's Future: A Strategy for Lawrence Livermore National Laboratory, Lawrence Livermore National Laboratory, Livermore, CA, UCRL-AR-12305, September 1997.

Department of Energy Strategic Plan: Providing America with Energy Security, National Security, Environmental Quality, and Science Leadership, Department of Energy, DOE/PO-00053, September 1997.

Stockpile Stewardship Plan: Second Annual Update (FY 1999), Department of Energy Office of Defense Programs, April 1998.

Laboratory Directed Research and Development FY 1998, Lawrence Livermore National Laboratory, Livermore, CA, UCRL-LR-113717-98, 1999.

Laboratory Research and Development: Innovation and Creativity Supporting National Security; Livermore, Los Alamos, and Sandia National Laboratories; Los Alamos, NM, LALP-97, April 1997.

Site Annual Environmental Report, Lawrence Livermore National Laboratory, Livermore, CA, UCRL-50027-98, September 1999.

LLNL Comprehensive Site Plan, Lawrence Livermore National Laboratory, Livermore, CA, UCRL-MI-110253-99, March 1999.

LLNL 1999 Executive Summary—Affirmative Action Plan for Women, Individuals with Disabilities, and Covered Veterans, Livermore, CA, UCRL-AR-111532-99-#XE-SUM.

6.3.2 *S&TR* Articles

Many scientific and technical topics in Sections 2, 3, and 4 have been discussed in fuller detail in the Laboratory's *Science & Technology Review* over the last few years. Article topics and their Internet addresses are listed below. Additional topics can be found using *S&TR*'s search engine. Hard copies are available through the Off-Site Requests Coordinator (address above).

Section 2
- Stockpile Stewardship: http://www.llnl.gov/str/Alonso.html
- Nonproliferation Support: http://www.llnl.gov/str/Dunlop.html
- Enhanced Surveillance of Weapons: http://www.llnl.gov/str/Kolb.html
- Reducing the Threat of Biological Weapons: http://www.llnl.gov/str/Milan.html

2.1.3
- High Explosives for Surveillance: http://www.llnl.gov/str/Lundberg. html
- Enhanced Surveillance of Weapons: http://www.llnl.gov/str/Kolb.html
- High Explosives: http://www.llnl.gov/str/Grissom.html
- Materials Aging: http://www.llnl.gov/str/Lemay.html

2.1.4
- Computer Simulations for ASCI: http://www.llnl.gov/str/Christensen.html
- Modeling High Explosives: http://www.llnl.gov/str/Simpson99.html
- Lasers for NIF: http://www.llnl.gov/str/Payne.html
- Laser Targets: http://www.llnl.gov/str/Lowns.html
- NIF Laser Developments: http://www.llnl.gov/str/Powell.html
- NIF Controls: http://www.llnl.gov/str/Vanarsdall
- TATB: http://www.llnl.gov/str/Pagoria.html

2.2.1
- Proliferation Prevention Technologies: http://www.llnl.gov/str/Dunlop.html
- Surplus Weapons from the Cold War: http://www.llnl.gov/str/Gray.html

2.2.2
- Seismic Monitoring: http://www.llnl.gov/str/Walter.html
- Soil Gases Detect Nuclear Explosions: http://www.llnl.gov/str/Carrigan.html

2.2.5
- Reducing the Threat of Biological Weapons: http://www.llnl.gov/str/Milan.html
- Forensic Science Center: http://www.llnl.gov/str/
- Technology and Policy: http://www.llnl.gov/str/Lehman.html

2.3.1
• Leveraging Science and Technology: http://www.llnl.gov/str/Coll.html
• High Explosives in Stockpile Surveillance: http://www.llnl.gov/str/Lundberg. html
• Explosives: http://www.llnl.gov/str/Kury.html
• Detonation Modeling with CHEETAH: http://www.llnl.gov/str/Fried.html

2.3.2
• Argus Protection System: http://www.llnl.gov/str/Davis.html
• Forensic Science Center: http://www.llnl.gov/str/Andresenhi.html

Section 3
• Energy Overview at LLNL: http://www.llnl.gov/str/Energy.html

3.1.1
• Argus Security Protection System: http://www.llnl.gov/str/Davis.html

3.1.2
• Corsica: Simulations for Magnetic Energy: http://www.llnl.gov/str/Cohen.html
• Hydrogen Fuel: http://www.llnl.gov/str/pdfs/03_96.3.pdf
• Electromechanical Battery: http://www.llnl.gov/str/pdfs/04_96.2.pdf
• Unitized Regenerative Fuel Cell: http://www.llnl.gov/str/Mitlit.html
• Carbon Dioxide in Global Warming: http://www.llnl.gov/str/Duffy.html

3.1.3
• Dangers of MBTE: http://www.llnl.gov/str/Happel.html
• ARAC Forewarns of Hazards: http://www.llnl.gov/str/Baskett.html
• Environmental Cleanup Basics: http://www.llnl.gov/str/Jackson.html
• Groundwater Cleanup—Hydrous Pyrolysis Oxidation: http://www.llnl.gov/str/Newmark.html

3.2.1
• Structural Biology: http://www.llnl.gov/str/Balhorn.html
• DNA Sequencing: http://www.llnl.gov/str/Ashworth.html
• High-Speed DNA Sequencing: http://www.llnl.gov/str/Balch.html

3.2.3
• Structural Biology: http://www.llnl.gov/str/Balhorn.html
• Kidney Gene with Human Genome Program: http://www.llnl.gov/str/Hamza. html

3.2.4
• Osteoporosis: http://www.llnl.gov/str/pdfs/06_96.3.pdf
• Ergonomics Research: http://www.llnl.gov/str/Burastero.html
• Peregrine: http://www.llnl.gov/str/Moses.html
• Technology for Stroke Attack: http://www.llnl.gov/str/

3.3.1
• Laser Experiments with Hydrogen: http://www.llnl.gov/str/Cauble.html
• Plasmas of Distant Stars: http://www.llnl.gov/str/Springer.html
• Acoustic Models and Algorithms: http://www.llnl.gov/str/Clark.html
• Material Behavior at the Atomic Level: http://www.llnl.gov/str/Moriarty.html
• Antimatter to Protect the Stockpile: http://www.llnl.gov/str/Howell.html
• Laser Guide Star and Adaptive Optics: http://www.llnl.gov/str/Olivier.html
• Metallic Hydrogen: http://www.llnl.gov/str/pdfs/Nellis.html
• Petawatt Laser: http://www.llnl.gov/str/Petawatt.html
• MACHO: http://www.llnl.gov/str/pdfs/04_96.1.pdf
• B-Factory: http://www.llnl.gov/str/VanBib.htm
• Microtechnology Center: http://www.llnl.gov/str/Mariella.html
• Atomic Engineering: http://www.llnl.gov/str/Barbee.html
• Petawatt Laser: http://www.llnl.gov/str/Petawatt.html

3.3.2
• 1997 R&D 100 Awards: http://www.llnl.gov/str/10.97.html
• 1998 R&D 100 Awards: http://www.llnl.gov/str/10.98.html
• 1999 R&D 100 Awards: http://www.llnl.gov/str/10.99.html

3.4.1
• 1999 R&D 100 Awards: http://www.llnl.gov/str/10.99.html
• 1998 R&D 100 Awards: http://www.llnl.gov/str/10.98.html
• LANDMARC for Land Mines: http://www.llnl.gov/str/Azevedo.html

3.4.2
• Methane Hydrate Surprises: http://www.llnl.gov/str/Durham.html
• B-Factory: http://www.llnl.gov/str/VanBib.html
• Visalia Cleanup: http://www.llnl.gov/str/Newmark.html

3.4.3
• Laser Collaboration with University of Rochester: http://www.llnl.gov/str/Olivier.html
• Center for Accelerator Mass Spectrometry: http://www.llnl.gov/str/Holloway.html
• Diamond Anvil Cell: http://www.llnl.gov/str/pdfs/03_96.2.pdf

• Positron Technology:
http://www.llnl.gov/str/Howell.html
• Bridge Seismology and Modeling:
http://www.llnl.gov/str/McCallen.html

Section 4
4.1.1
• Lasers for NIF:
http://www.llnl.gov/str/Payne.html
• Laser Targets:
http://www.llnl.gov/str/Lowns.html
• Laser Developments for NIF:
http://www.llnl.gov/str/Powell.html
• National Ignition Facility Controls:
http://www.llnl.gov/str/Vanarsdall

4.1.2
• Computer Simulations for ASCI:
http://www.llnl.gov/str/Christensen.html

4.1.4
• TATB:
http://www.llnl.gov/str/Pagoria.html

4.1.5
• High Explosives in Stockpile Surveillance:
http://www.llnl.gov/str/Lundberg.html

4.2.1
Technology and Policy:
http://www.llnl.gov/str/Lehman.html

4.2.3
• Reducing Biological Weapon Threat:
http://www.llnl.gov/str/Milan.html

4.3.1
• Carbon Dioxide in Global Warming:
http://www.llnl.gov/str/Duffy.html
• Energy Overview at LLNL:
http://www.llnl.gov/str/Energy.html

4.3.3
• DNA Sequencing:
http://www.llnl.gov/str/Balch.html
• Kidney Gene with Human Genome Program:
http://www.llnl.gov/str/Hamza.html

4.3.8
• Positron Technology:
http://www.llnl.gov/str/Howell.html

4.4.2
• Hydrogen Fuel:
http://www.llnl.gov/str/pdfs/03_96.3.pdf
• Unitized Regenerative Fuel Cell:
http://www.llnl.gov/str/Mitlit.html

4.5.1
• Nuclear Waste:
http://www.llnl.gov/str/pdfs/03_96.1.pdf
• Fusion Plan Cleanup:
http://www.llnl.gov/str/pdfs/06_96.2.pdf
• Surplus Weapons from the Cold War:
http://www.llnl.gov/str/Gray.html
• Energy Overview at LLNL:
http://www.llnl.gov/str/Energy.html

4.5.2
• B-Factory:
http://www.llnl.gov/str/VanBib.html
• Positron Technology:
http://www.llnl.gov/str/Howell.html

4.5.3
• Computational Mechanics:
http://www.llnl.gov/str/Raboin.html

6.4 Lawrence Livermore's Fact Sheets

The fact sheets on the following pages were developed for the Laboratory Operations Board in January 1999 and reflect the work of FY 1998, with minor updates in November 1999. The funding categories, which are not identical to those in the resource projections, are sorted according to precise requirements for the profile.

Lawrence Livermore National Laboratory Fact Sheets

Laboratory Statistics

Location: Livermore, California

Number of Full-Time Equivalent Employees: 7,300
Scientific and Technical Degrees: 1,200 Ph.D's., 1,600 Bachelor's/Master's
Contractor: University of California
Accountable Program Office: DOE Defense Programs
Field Office: DOE/Oakland Operations Office
Web Site: http://www.llnl.gov

Funding Sources

Defense Programs: $757.0 million

Nonproliferation and National Security: $85.5 million
Science: $72.0 million
Environmental Management: $67.1 million
Fissile Materials Disposition: $25.2 million
Nuclear Energy: $7.4 million
Other DOE: $72.2 million
Non-DOE: $170.6 million

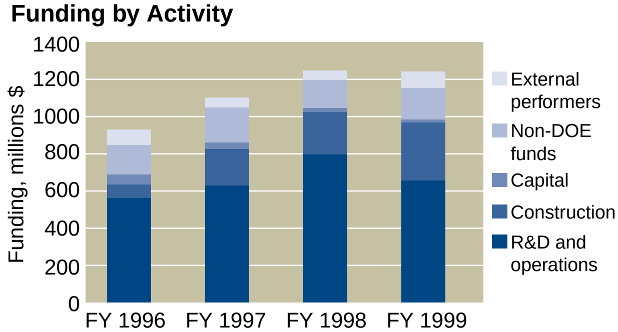
Description

Lawrence Livermore National Laboratory is a national security laboratory with responsibility for ensuring that the nation's nuclear weapons remain safe, secure, and reliable. We also have a primary role in the Department of Energy's mission in the prevention of the spread and use of nuclear weapons, as well as other weapons of mass destruction. Established in 1952 to augment the nation's nuclear weapons design capability, Livermore made major advances in nuclear weapons safety and performance throughout the Cold War. To address national security needs, the Laboratory has pioneered the application of technologies ranging from high-performance computers to advanced lasers, and it has gained multiprogram responsibilities that drew on Livermore's multidisciplinary expertise. Today, our special capabilities, required for stockpile stewardship and nonproliferation activities, enable us to meet enduring national needs in conventional defense, energy, environment, biosciences, and basic science. Research and development (R&D) programs in these areas enhance the competencies needed for the Laboratory's national security mission. Livermore serves as a resource to the U.S. government and as a partner with industry and academia.

Distinctive Competencies and Major Facilities

High-Energy-Density Physics and Nuclear Science and Technology: Broad expertise in nuclear weapons, fission energy, and fusion programs, with exceptional capabilities for investigating the properties of matter at extreme conditions. Facilities: National Ignition Facility (NIF) (under construction), ultra-short-pulse lasers, Plutonium Facility, and Flash X-Ray Facility.
Advanced Lasers and Electro-Optics: Preeminence in laser science and technology, supporting stockpile stewardship; many other laser and electro-optics applications with NIF (under construction), the Center for Microtechnology, and development of extreme ultraviolet lithography (EUVL) with industry.
High-Performance Scientific Computing: A 3.9-teraops supercomputer being installed and a 10-teraops capability planned for FY 2000 to support stockpile stewardship, offering the potential for major advances in climate modeling, environmental studies, materials science, and many areas of physics.
Materials Science: Special capabilities for materials design, synthesis, processing, characterization and simulation for stockpile stewardship, energy and environmental R&D, and nuclear materials management with our High-Explosives Application Facility, Plutonium Facility, and other special facilities.
Multidisciplinary, Integrated Approach to Problem Solving: Activities ranging from fundamental science to production engineering of complex systems. A multidisciplinary-team approach provides unique strengths for national security applications and biotechnology and environmental hazard characterizations. Facilities: Joint Genome Institute and Livermore's Human Genome Center, Forensic Science Center, and Center for Accelerator Mass Spectroscopy.
Computer Simulation of Complex Systems with Experimental Validation: Support for stockpile stewardship, magnetic fusion R&D (CORSICA simulation, spheromak), nuclear waste repository R&D, and validated models for the National Atmospheric Release Advisory Center.

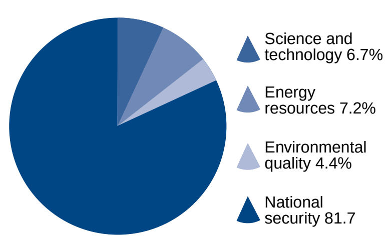
Funding by Activity



Note: Site remediation funds excluded.

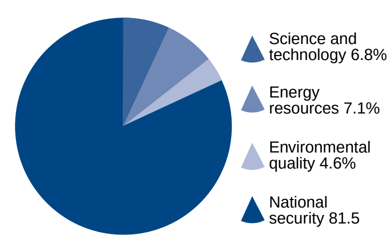
DOE R&D Footprint

Total R&D: $1,061.5 million



DOE Mission Footprint

Total Mission: $1,064.8 million



Note: Based on FY 98 funding data; contributing non-DOE funds include; site remediation funds excluded.

Key Research and Development Activities

National Security is the Laboratory's defining responsibility. As one of DOE's three national security laboratories, Livermore plays a prominent role in the Stockpile Stewardship Program and addresses the increasingly serious problem of the proliferation of weapons of mass destruction (WMD). We also develop advanced technologies for other sponsors' national security needs, pursues major projects in areas where it can make unique and valuable contributions, particularly focusing on program areas that reinforce the Laboratory's national security work. Application of our special skills to selected efforts in **Energy Resources**, **Environmental Quality**, and **Science and Technology** leads to cross-fertilization of ideas. In turn, program diversity keeps the Laboratory vital and helps to sustain the multidisciplinary base needed for our national security mission.

National Security Mission

Stockpile Stewardship: Maintenance of the nuclear weapons stockpile, assurance of weapon safety and reliability, and certification of performance in the absence of nuclear testing. The Laboratory is part of DOE's integrated program of surveillance (including efforts to better predict aging phenomena), assessment (validated by simulation and experiments), refurbishment of stockpile components, and production of tritium. Principal activities:
• Stockpile Surveillance—special responsibility for stockpile weapons that the Laboratory designed (W87 and W62 ICBM warheads, B83 bomb, and W84 cruise missile warhead) and efforts to build the scientific base and develop monitoring capabilities to understand aging effects in all stockpiled weapons.
• Stockpile Assessment—comprehensive activities to provide the foundation for stockpile certification and refurbishment decisions based on scientific and engineering demonstrations through an integrated program of computational simulation, fundamental scientific research, and experiments. Major investments at the Laboratory to markedly improve assessment capabilities include: Blue Pacific and Option White (Accelerated Strategic Computing Initiative [ASCI] supercomputers to simulate the performance of an aging stockpile and conditions affecting weapon safety) and the National Ignition Facility (a 192-beam laser to achieve fusion ignition and study the thermonuclear properties of weapon primaries and secondaries).
• Stockpile Refurbishment—The W87 Life Extension Program as well as development (with production plants) of advanced manufacturing technologies (Laser Cutting Workstation for Y-12) to improve quality and lower costs and environmental impact of refurbishment work.
• Integrated Program Management—Key contributions to the development of the Stockpile Stewardship Program's detailed implementation plan (the Green Book) and to formal review processes for certification of weapon safety and reliability (annual certification and dual revalidation).
Countering WMD Proliferation and Use: The Laboratory's expertise in nuclear weapons, developed over time through our weapons program and continuing stockpile responsibilities, is employed to counter the challenge of nuclear nonproliferation. Our large investment in chemical and biological science yields technology development and expertise for stemming the spread of WMD. Principal activities:
• Nonproliferation and Arms Control—Analysis and technical support for arms control negotiations, nuclear safeguards, export control, and regional security.
• Monitoring Technologies—R&D of remote sensing, monitoring, and assessment technologies to detect WMD activities.
• International Assessments—Assessment of the capabilities and motivations of foreign programs to develop or produce WMD.
Technology Development for National Security: Support to other agencies in meeting requirements and addressing emerging threats (see Major Partnerships).

Energy Resources Mission

The Laboratory pursues projects aimed at significant, large-scale innovations in energy production and usage. We also serve as an effective national technical resource in the management of nuclear materials. Activities (also see Fusion Energy Research below):
• Nuclear Materials—Modeling, engineering design, field testing, and lab experiments to ensure long-term containment of radionuclides; R&D in key aspects of the nuclear fuel cycle, including fission energy, to guide and support domestic and international programs.
• Carbon Management—Technology development for fuel efficiency (e.g., fuel cells and hydrogen-fuel capability), fossil fuel recovery, and CO_2 sequestering.

Environmental Quality Mission

The Laboratory's efforts are directed at demonstrating effective environmental remediation technologies, advancing the science base for environmental regulation, and accurately modeling regional weather and global climate conditions. Activities include:
• Global and Regional Climate Modeling—R&D on climate and atmospheric processes such as model development, intercomparison, and validation.
• National Atmospheric Release Advisory Center—Near-real-time modeling to assist emergency response if radioactive or toxic materials are released.
• Environmental Management—Environmental cleanup technologies R&D and demonstration here and at other sites.
• Environmental Risk Reduction—Development of models and technologies to assess environmental consequences of toxic materials and manage risks.

Science and Technology Mission

Activities bolster our research strengths and contribute to solving important national problems. For example, bioscience research both contributes to the national security mission and leverages physical science engineering capabilities. Activities include:
• Bioscience and Biotechnology—Multidisciplinary R&D including genomics, disease susceptibility, national security, and health-care technology.
• Fusion Energy Research—Computations and experiments to advance the physics and technologies for magnetic fusion and inertial confinement fusion.
• Lasers and Electro-Optics—Advanced manufacturing and microfabrication (laser guide star, precision cutting, lithography).
• Computer Science and Simulation—High-performance computing and information management, software technology development, and systems integration.
• Materials Science—R&D to understand the design, simulation, synthesis, processing, and properties of existing and novel materials.
• Astrophysics and Space Science—R&D on high-energy-density astrophysical processes and sensors for space systems and astrophysics research.
• Accelerator Technology—R&D for the SLAC B-Factory and future accelerators; activities include design innovation, systems engineering, and precision manufacturing.

Significant Accomplishments

Certification of the U.S. Nuclear Weapons Stockpile: For the third straight year, the directors of Lawrence Livermore, Los Alamos, and Sandia national laboratories certified to DOE that no nuclear testing was needed to ensure the safety and reliability of the nuclear weapons stockpile. A comprehensive technical review supported the 1998 Annual Certification Report and the stockpile certification memorandum sent to the president.

National Ignition Facility (NIF) Construction: In May 1997, a groundbreaking ceremony launched construction of NIF, a cornerstone of the Stockpile Stewardship Program. The target chamber was put in place in June 1999. The 192-beam laser will enable well-diagnosed experiments to examine fusion burn and study the thermonuclear properties of primaries and secondaries in nuclear weapons and validate related computer models.

Record-Setting Hydrodynamic Calculation: In October 1998, a team of Laboratory and IBM personnel performed the largest hydrodynamic calculation ever attempted in preparation for delivery of the 3.9-teraops (trillion operations per second) Blue Pacific machine to Livermore as part of ASCI. The calculation, a factor of 100 larger than the previous record, had 25 billion zones and ran at a sustained rate of 1 teraops.

Subcritical Experiments to Understand the Properties of Plutonium: In September 1997, we conducted our first subcritical experiment at the Nevada Test Site and in September 1998 fielded a second very successful test. These experiments contribute to a better fundamental understanding of this metal and the effect of aged plutonium on stockpile performance.

W87 Stockpile Life Extension: In 1998, the Laboratory completed the final engineering design of the refurbishment of the W87 ICBM warhead, extending its lifetime to beyond 2025. Activities included ground testing, high-fidelity flight testing (including several major technical innovations), physics and engineering analysis, and design recertification.

Record-Breaking Laser and Award-Winning Applications: In 1997, we developed the world's most powerful laser. The ultrashort-pulse petawatt laser technology opens new directions in inertial confinement fusion research and led to an R&D 100 Award-winning spinoff: a safe, extremely precise tool for machining virtually any type of material, to be used in stockpile refurbishment programs.

Fast, Portable Sensors for Biological Agent Detection: Polymerase chain reaction (PCR) analysis of a bacterial warfare surrogate was demonstrated this year using a portable Laboratory-designed instrument that analyzes samples of 5 to 500 bacteria cells in as little as 7 minutes. Versions of this technology are being provided to the U.S. Navy and Army to support their bioresponse units.

Waste Form for Plutonium: We have the technical lead in DOE's Plutonium Immobilization Program. Our staff defined compositions for the glass and ceramic candidate forms for immobilizing excess U.S. plutonium, characterized them for proliferation resistance and performance, developed information needed to evaluate concepts for production processes, and in 1998 completed a peer-reviewed evaluation of the waste forms.

Counterproliferation Analysis and Planning System (CAPS): The Laboratory has developed and continues to improve CAPS. CAPS is accepted by DoD customers as a valuable counterproliferation planning tool for analyzing a country's proliferation activities, determining the function of suspected sites, and identifying critical processing steps or facilities which, if denied, would prevent acquisition of weapons of mass destruction.

Joint Genome Institute (JGI) Sequencing Goals: The Institute (Livermore, Los Alamos, and Berkeley laboratories) entered into production mode for sequencing DNA. The FY 1998 goal was achieved with over 20.9 million base pairs sequenced, a tenfold increase over FY 1997 efforts. The Institute continues to step up the production schedule, relying on high throughput microchannel sequencing instrumentation developed by Livermore.

Coupled Ocean-Atmosphere Global Climate Models: The Laboratory improved the physics in codes and developed powerful new models that treat the atmosphere and oceans as a coupled system. Results are in closer agreement with observed regional temperature trends.

Accelerated Groundwater Cleanup: We developed and demonstrated methods to greatly accelerate groundwater cleanup at the Livermore site. In 1998, these remediation technologies were used at a Superfund site in Visalia, California. Soil and groundwater cleanup was nearly 5,000-fold faster than conventional pump and treat techniques.

Discovery of Massive Compact Halo Objects (MACHOs): In 1996, Livermore scientist Dr. Charles Alcock received the E. O. Lawrence Award for his leadership in the hunt for "dark matter," one of the great mysteries of cosmology. The search for MACHOs, a form of dark matter that could account for 50% of our galaxy's mass, uses an R&D 100 Award-winning optical imaging system developed here.

Clementine Maps the Moon: In 1994, the Clementine Deep Space Experiment with a Livermore-designed sensor suite collected over 1.7 million images during its two months in lunar polar orbit and demonstrated a "faster, cheaper, better" approach to doing business in space. Clementine data enabled the first detailed investigation of the geology of the lunar far side and polar regions and provided first evidence for polar ice.

Nobel Prize Science and R&D 100 Award-Winning Innovations: The 1998 Nobel Prize for Physics was shared by Stanford Professor Robert Laughlin, an associate of the Laboratory for 17 years. In 1999, Livermore researchers and their industrial partners earned 6 R&D 100 Awards. These awards bring to 80 the number of R&D 100 Awards won by Livermore researchers.

Major Partnerships, Collaborations, and Cooperative Research and Development Agreements

Category/Mission	Partner	Description
National Security		
• Other DOE	Other DOE/DP sites	Stockpile Stewardship, a Defense Programs complex-wide integrated program: multi-lab research efforts, production technology development with plants, experiments at NTS
• Universities	Stanford U., Caltech, U. of Utah, U. of Illinois	Academic Strategic Alliances Programs (ASAP) centers supporting ASCI by accelerating advances in large-scale computational simulation
• Universities	U. of Rochester	Inertial confinement fusion program, including use of the Omega laser
• Industry	IBM and other firms; precision-optics firms	Technology development and acquisition for stockpile stewardship: ASCI Blue Pacific, Option White, and PathForward; advanced technologies for NIF
• Other DOE	Other DOE labs and facilities	Nonproliferation activities: immobilization of plutonium in proliferation-resistant waste forms; Joint Technical Operation Team for WMD incident response
• International	Russian defense laboratories and others	Materials protection, control & accounting projects with other DOE labs at 53 sites in FSU and other U.S.-Russian "Lab-to-Lab" programs
• Other Federal Agencies	Department of Defense	Advanced munitions and sensors; energetic materials; computer tools for design and analysis; counterproliferation support; microsatellite and BMD technologies
• Other Federal Agencies	Various agencies	Analysis support and technology development (intelligence community); arms control analysis and support (State Dept.); forensic science and counterterrorism technologies (FBI)
Science and Technology		
• Other DOE	SLAC and LBNL (and others)	The SLAC B-factory (and other accelerators), contributing design innovations, systems engineering, and precision manufacturing
• Other DOE	LBNL and LANL	Technology development and operation of the Joint Genome Institute for "production mode" sequencing of DNA and characterization
• Other Federal Agencies	National Institutes of Health	Bioscience research in DNA repair, reproductive biology, biodosimetry, and mutagenesis
• Universities	Washington U.-Merck and others	I.M.A.G.E. Consortium (the largest public collection of sequenced cDNA clones, at LLNL); collaborations to identify genes causing debilitating diseases
• Universities	University of California and others	Five Laboratory and University of California collaborative institutes; with 1,600 laboratory–university collaborations (faculty, research staff, and students)
• Universities	Various universities and others (user facility)	Center for Accelerator Mass Spectrometry: extremely sensitive measurement capability supporting diverse research efforts (20,000 samples/year)
• Industry	Limited Liability Corp. (Intel-led consortium)	With LBNL and SNL, development of extreme-ultraviolet lithography for the manufacture of next-generation computer chips
• Industry	Various companies	CRADAs, e.g., in advanced lasers and electro-optics (laser peening, precision manufacturing) and medical technologies (digital mammography, stroke treatment)
Environmental Quality		
• Industry	So. Cal. Edison and SteamTech Environmental Services	Technology demonstration on cleanup technologies (dynamic stripping and hydrous pyrolysis) at Superfund site in Visalia, California
Energy Resources		
• Industry	Various companies	Technology development as part of DOE's Natural Gas and Oil Technology Partnership
• Other Federal Agencies	Nuclear Regulatory Commission	Development and certification of radioactive material and spent-fuel transportation packages

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